Concord Scientific Corporation

2 TIPPETT RD., TORONTO, ONTARIO, CANADA M3H 2V2 TELEPHONE: (416) 630-6331 FAX: (416) 630-0506

RISK ASSESSMENT/MANAGEMENT STUDY

OF RAIL CORRIDORS IN THE CITY OF TORONTO

Prepared for

The City of Toronto
Planning and Development Department

by

Concord Scientific Corporation

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SUMMARY

This study has been conducted on behalf of the City of Toronto to assist its Planning and Development Department in its examination of suitable land use regulatory measures for rail corridors, which incorporate public safety/risk considerations. The intent of this investigation was to extend the large area risk assessment and management study undertaken in 1986-87 for the Toronto Area Transportation of Dangerous Goods Task Force, focusing on the specific hazards to the public posed by dangerous goods (DG) and non-DG rail traffic within the City of Toronto. The primary focus of this report is the risk to the public due to DG rail traffic within the City, particularly along the main freight corridor (the CP Galt and North Toronto railway subdivisions).

The study commenced with data collection and identification of key situations in the City where public safety is threatened by potential rail transportation accidents and existing land uses adjacent to rail corridors. The identified sites and hazards were reviewed in conjunction with City officials and its Technical Advisory Committee and they fall into two categories: fixed hazardous facilities having the potential to escalate the consequences of a railway accident (the so-called "knock-on effect") and public facilities of key concern being those particularly vulnerable to rail accidents, such as schools and senior citizens residences. Along the main freight corridor, nine fixed hazardous facilities were identified, of which six were selected as representative industrial land use facilities involving DGs; and, six public facilities of key concern were identified, of which four were selected as representative of high density and vulnerable residential land use facilities. The selected sites were used as representative land uses for valuation of the lands with respect to possible set-back distances.

The potential consequences of a rail accident near these 15 fixed hazardous facilities and public facilities of key concern have been discussed in qualitative terms. Quantitative analyses of potential knock-on effects were not within the scope of this study. And while quantitative analyses were also not required for the risks specific to each public facility,

detailed population data in the area of all 15 key facilities were used, for the quantitative estimates of public risk from DG rail transport accidents.

A quantitative analysis of risk from DG rail transport was conducted for the approximately 96 km of rail network carrying DG trains within the City limits. The risks were analyzed on the basis of 13 rail segments comprising four corridors in the rail network as shown in Figure 2-1:

- Corridor I (Segments 1, 2 and 3): the main freight corridor running west-east in the north of the City consisting of the CP North Toronto and Galt subdivisions.

- Corridor II (Segments 8, 10, 11 and 13): the main passenger corridor running west-east in the south of the City consisting of the CN Oakville and Kingston subdivisions.

- Corridor III (Segments 4, 5, 6, 7 and 9): the roughly north-south corridor in the west of the City consisting of the CN Weston and Newmarket subdivisions as well as the CP Galt and McTier subdivisions.

- Corridor IV (Segment 12): the north-south corridor in the east of the City consisting of the CN Bala and CP Belleville subdivisions.

Estimates of individual and societal risk were made for each rail segment as well as the entire network. The measure of risk was taken as immediate death as is the practice in such risk studies. Delayed deaths or sub-lethal effects from exposure to hazards were not considered in the quantitative analysis. Residential and employment population data used were from 1988 and transients (visitors and commuters) were not included. Data on railroad accident frequencies and DG rail traffic volumes were the same as 1985 data employed in the Toronto Area Rail Transportation of Dangerous Goods Task Force risk

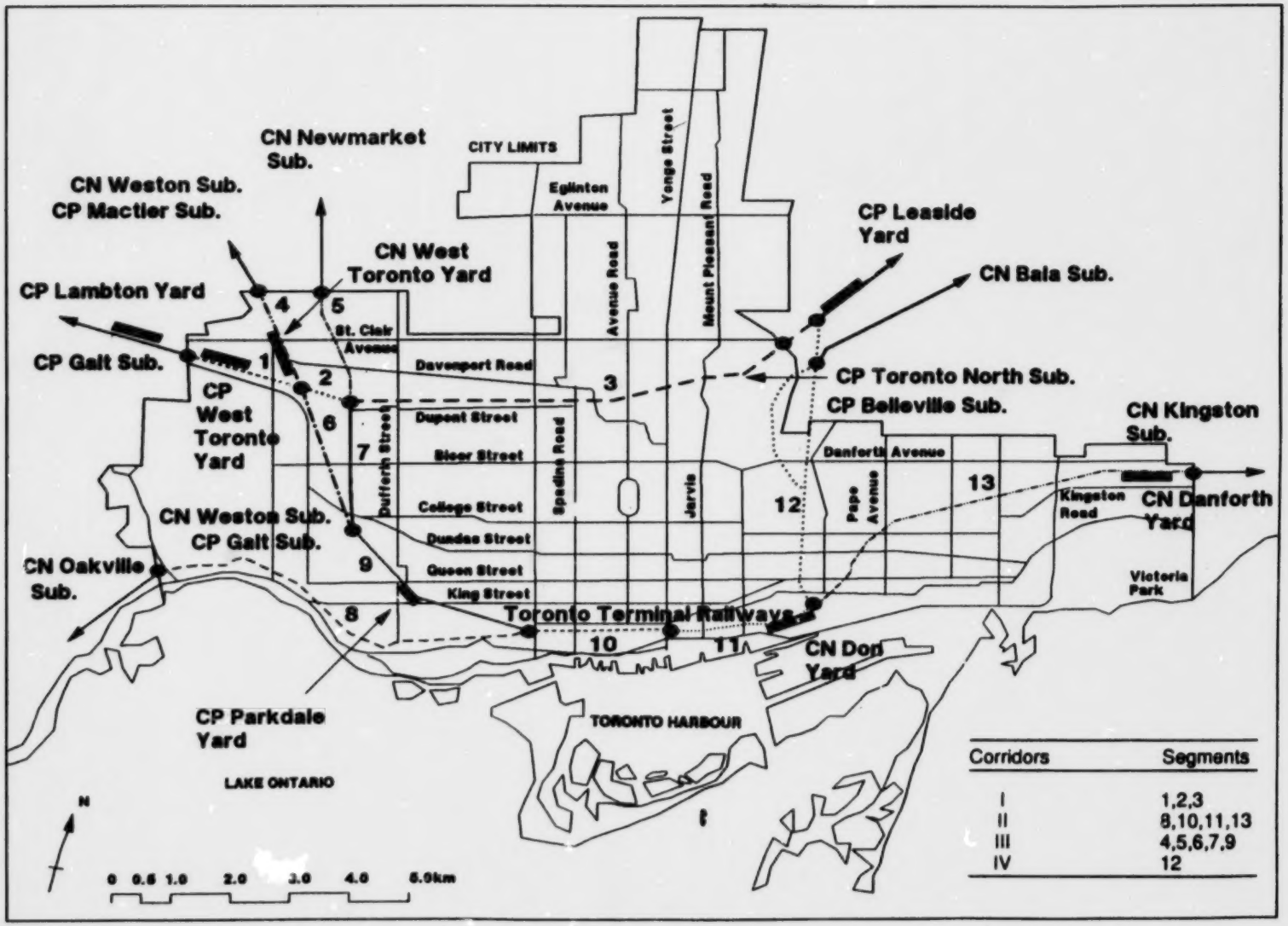

FIGURE 2.1 CITY OF TORONTO STUDY AREA AND RAIL SEGMENTS

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assessment by Concord Scientific Corporation, except for the CP rail traffic data which was revised based on its 1988 traffic movements which are more representative of current operations.

The societal risk or the overall risk to the public from DG rail transport within the City was estimated at 0.322 fatalities per year (or 1 fatality per 3.1 years). A similar study for the City of Denver in 1987 estimated a comparable level of societal risk of 0.278 fatalities per year (or 1 fatality per 3.6 years). These levels of societal risk, when compared to common societal risks, were shown to be relatively small for both cities. The average individual risk of fatality for the City of Denver, with a population of approximately 500,000 was given as 0.56 chances in a million per year which is also comparable to the estimate of 0.5 chances in a million per year for the City of Toronto, with a population of about 608,000.

While the overall societal risk is relatively small, some regions of the City bear much higher risks than do others. On examining societal risks on a segment-by-segment basis, it was shown that the highest levels of societal risk are posed by rail segments along the main freight corridor. The societal risk rate along the highest risk segment is about 90 times higher than that along the lowest risk segment. Of the estimated overall societal risk due to DG rail transport in the City, the three rail segments of the main freight corridor account for 41%.

Profiles showing the estimated levels of individual risk as a function of distance from the rail line were produced for all rail segments. The estimated values of maximum individual risk of fatality are below 100 chances in a million per year (a relatively high risk level, comparable to the individual risk of falls in the City) for all rail segments except those along the main freight corridor, where within 30 m of segment 2, levels of individual risk reach 100 to 115 chances in a million per year. Only rail segments 1 to 4 pose individual risk of fatality of greater than 10 chances in a million per year at the edge of the railway right-of-way (approximately 10 m from the rail line). All rail

segments pose individual risk of fatality of greater than 1 chance in a million per year at the edge of the railway right-of-way.

When the evaluating estimates of risk, it is important to bear in mind that there are uncertainties in making such estimates. The uncertainty in the mortality risk values presented in this report are considered to be in a range from a value two times higher to a value of ten times lower than the estimate given. For example, an individual risk estimate of 10 chances in a million per year could lie in the range of 20 to 1 chance in a million per year. It should also be noted that the risk estimates provided are based on the specified DG traffic volumes and population (which does not include transients (i.e., non-residents, commuters and visitors). Any significant changes to these two primary determinants of public risk would produce significant changes to the risk estimates. As the DG traffic volumes and the resident population of the City of Toronto are not expected to change significantly in the forseeable future, the risk estimates presented in this report are considered reasonably representative of existing and near- future conditions.

Judgements about the acceptability of risk are personal and social value judgements that can only be made by the public exposed to the risk and their elected representatives in government. To assist decision makers and other parties concerned with evaluating the acceptability of the estimated levels of risk, data were compiled on common involuntary risks in the City and some criteria on acceptability from the literature and other jurisdictions are provided. As the field of risk analysis is relatively young, no universally accepted risk criteria exist, and in Ontario and Canada as a whole, no formal risk guidelines or standards have been adopted. Experience is building, however, as many jusidictions are facing public risk management decisions. Consensus is forming that levels of individual risk of death per year of less than one chance in a million are not significant. With regard to upper bounds on the acceptability of individual risk per year, the level of 10 chances in a million appears to be receiving increasing attention and has been adopted in some jurisdictions.

The use of set-backs, as a risk mitigation, were shown to provide significant levels of risk reduction. Compared to a set-back of zero metres (roughly 10 m from rail line), set-backs of 30 to 100 m were estimated to reduce maximum levels of individual risk by 25 to 88%, along the main freight corridor. Given the existence of 30 m set-backs, the reduction in maximum individual risk was estimated to be 13 to 77% through implementation of 50 to 100 m set-backs along the main corridor. The corresponding percentage reductions in societal risk were estimated to be 40 to 76%.

Costs to implement set-backs along the main freight corridor were estimated based on land valuations using three categories of development: industrial, residential and commercial. The land valuations are based on an analysis of the expected market value of the property from putting it to its highest and best use. Therefore, the estimated costs should be viewed as "lost opportunity costs" to the landowners. These costs estimates given below are based on 1989 values and are considered approximate.

SET-BACK DISTANCE (M)	COST ($ MILLIONS)			
	INDUSTRIAL	RESIDENTIAL	COMMERCIAL	TOTAL
30	9	71	142	222
50	23	161	499	683
100	85	324	1,916	2,386

Therefore, to implement a 30 to 100 m set-back for all development along the entire corridor would cost in the range of $220 million to $2.4 billion. While not a requirement of this study, it should be noted that no analysis has been done on the benefits that would accrue to the city from added land values were relocation of the rail lines to take place as opposed to implementation of set-backs as the measure for risk mitigation.

A review of studies pertaining to the objectives of the present investigation is presented for four Canadian cities: Regina, Calgary, Vancouver and Toronto; and two U.S. cities:

Seattle and Denver. While the issue of public risk from rail transportation has been examined in one form or another in these studies, no DG risk-based set-backs have been adopted in the Canadian cities. The City of Regina has implemented a municipal by-law stipulating a 300 m set-back (buffer zone) for residential development, based, however, primarily on noise abatement considerations. The Denver study was found to be the most relevant of the studies reviewed and a 30 m set-back was recommended in this study to reduce levels of individual risk to less than one chance in a million per year. A detailed examination of other risk mitigation measures was also undertaken in this study.

For the authors of this report to make firm recommendations to the City regarding the sizes of set-backs that should be implemented would not be appropriate, as this would require value judgements to be made on the levels of risk which would be acceptable to the public. These are social value judgements that can only be made by the public or their elected representatives. This report has documented the risk estimates and some common City risks and risk criteria from other jurisdictions have been provided to assist City officials and other interested parties in evaluating the acceptability of the estimated risks.

In order to satisfy the requirements of this study and provide recommendations for risk reductions with respect to set-back distances, without making the above noted value judgements nor making assumptions as to the risk criteria that City Council might adopt, a range of options has been prepared for the main freight corridor in consultation with the City's Planning Department. They are as follow in order of increasing risk reduction:

OPTION 1A: 30 METRE SETBACK FROM RIGHT-OF-WAY FOR RESIDENTIAL DEVELOPMENT AND PLACES OF ASSEMBLY (I.E., SCHOOLS)

OPTION 1B: 30 METRE SETBACK FROM RIGHT-OF-WAY FOR ALL DEVELOPMENT (INDUSTRIAL, COMMERCIAL, RESIDENTIAL)

OPTION 2A:	50 METRE SETBACK FROM RIGHT-OF-WAY FOR RESIDENTIAL DEVELOPMENT AND PLACES OF ASSEMBLY
OPTION 2B:	50 METRE SETBACK FROM RIGHT-OF-WAY FOR ALL DEVELOPMENTS
OPTION 3A:	100 METRE SETBACK FROM RIGHT-OF-WAY FOR RESIDENTIAL DEVELOPMENT AND PLACES OF ASSEMBLY
OPTION 3B:	100 METRE SETBACK FROM RIGHT-OF-WAY FOR ALL DEVELOPMENT

The lost opportunity costs for these options range from about $76 million for Option 1A to $2.4 billion for Option 3B. The reductions in risk vary for Segments 1, 2 and 3 of the main freight corridor and they are given in Section 5 of the report. In general, set-backs of 30 to 100 m were estimated to reduce maximum levels of individual risk along the main freight corridor by 25 to 88% compared to the case of a set-back of zero metres (roughly 10 m from rail line).

No set-back option has not been presented, given that some parts of the main freight corridor have estimated levels of individual risk of fatality of greater than 100 chances in a million per year. Such levels are generally considered high and other jurisdictions appear to be adopting 10 chances in a million as an upper bound on acceptable individual risk.

With regard to segments 4 through 13, a set-back of 30 m may be a suitable set-back for the City to consider since it would reduce levels of individual risk to generally well below 10 chances in a million per year and is consistent with railway policy. Cost estimates for set-backs along these segments was not a requirement of this study.

However, for the main freight corridor, it is recommended that other risk mitigation measures be seriously considered in addition to set-backs, which even at 100 m would not

reduce estimated maximum levels of individual risk to below 10 chances in a million along the entire corridor. A general and qualitative discussion of the following other forms of risk mitigation is presented in the report: land-use restrictions; barriers or barricades; tunnels; time-of-day scheduling; rerouting; speed restrictions; improved training of rial and emergency response personnel; inspection programs for rail cars and railway track and bed conditions; drainage controls; and increased protection at level crossings. The first measures that should be considered are those that are directly within the control of the City, such as land-use restrictions, barriers and drainage controls. A detailed examination of these and other risk mitigation measures would need to be undertaken before site specific recommendations could be made.

ACKNOWLEDGEMENTS

This study would not have been possible without the cooperation of a number of individuals and agencies: the Federal Department of Transport granted approval for the use of the data base developed for the risk study undertaken by Concord for the Toronto Area Rail Transportation of Dangerous Goods Task Force; Canadian National and Canadian Pacific Railways also approved for the present study the use of data for this study that they had supplied for Task Force risk study; Canadian Pacific cooperated further in the provision of additional data relating to traffic flows; the Canadian Institute of Guided Ground Transport performed, under sub-contract, the disaggregation of accident frequency data into freight and passenger train components; Marshall Macklin Monaghan performed, under sub-contract, the cost estimation for buffer implementation in the City of Toronto; Transmode Consultants performed, under sub-contract, an up-dated analysis of DG traffic flows on CP's rail lines; the City of Toronto's Department of Public Works supplied road traffic at level crossings; the Planning and Development Department of the City of Toronto contributed to specific tasks to this study, in particular relating to population data, fixed industrial and institutional facilities, in addition to providing review and comments on the work; and the City's Technical Advisory Committee supplied valuable information as well as providing review and comments on the work.

The contributions of these agencies and the individuals involved are gratefully acknowledged.

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1.0 INTRODUCTION

1.1 STUDY PURPOSE

This study has been conducted on behalf of the City of Toronto to assist its Planning and Development Department in its examination of suitable land-use regulatory measures for rail corridors, which incorporate public safety/risk considerations.

The study extends the risk assessment and risk management study undertaken by Concord Scientific Corporation for the Greater Toronto Area (Concord, 1987). The present work focusses on the specific hazards to the public posed by dangerous goods (DG) rail traffic within the City of Toronto (hereinafter referred to as the "City"), in particular, along the main freight corridor (the CP Galt and North Toronto subdivisions).

The primary objective of this report is the provision of guidance for the establishment of set-backs and suitable land-use measures for DG rail corridors based upon analysis of the risks to the public and the costs associated with different set-back distances if they were to be implemented as risk mitigation measures. The specific terms of reference for this work are contained in Appendix A along with the major changes that were made to the scope of work.

1.2 BACKGROUND ON PUBLIC RISK CONSIDERATIONS

The hazards associated with rail traffic are generally well known. A rail accident could potentially expose the public in the vicinity of the accident to the following hazardous events:

- toxic gas cloud resulting from a release of a dangerous chemical from a ruptured tank car;

- fires and/or explosions of a flammable substance released from a ruptured tank car; and

- physical impact.

The risk to the public from such hazards is addressed in this report. The term "risk" can be defined as follows in relation to the term "safety". Safety is a judgement of the acceptability of risk and risk, in turn, is a measure of the probability and severity of harm to humans. There are degrees of risk and, therefore, there are degrees of safety. Determining safety involves two very different kinds of activities, as depicted in Figure 1.1.

a) Risk Analysis: measuring the probability and severity of harm – an empirical, scientific activity; and

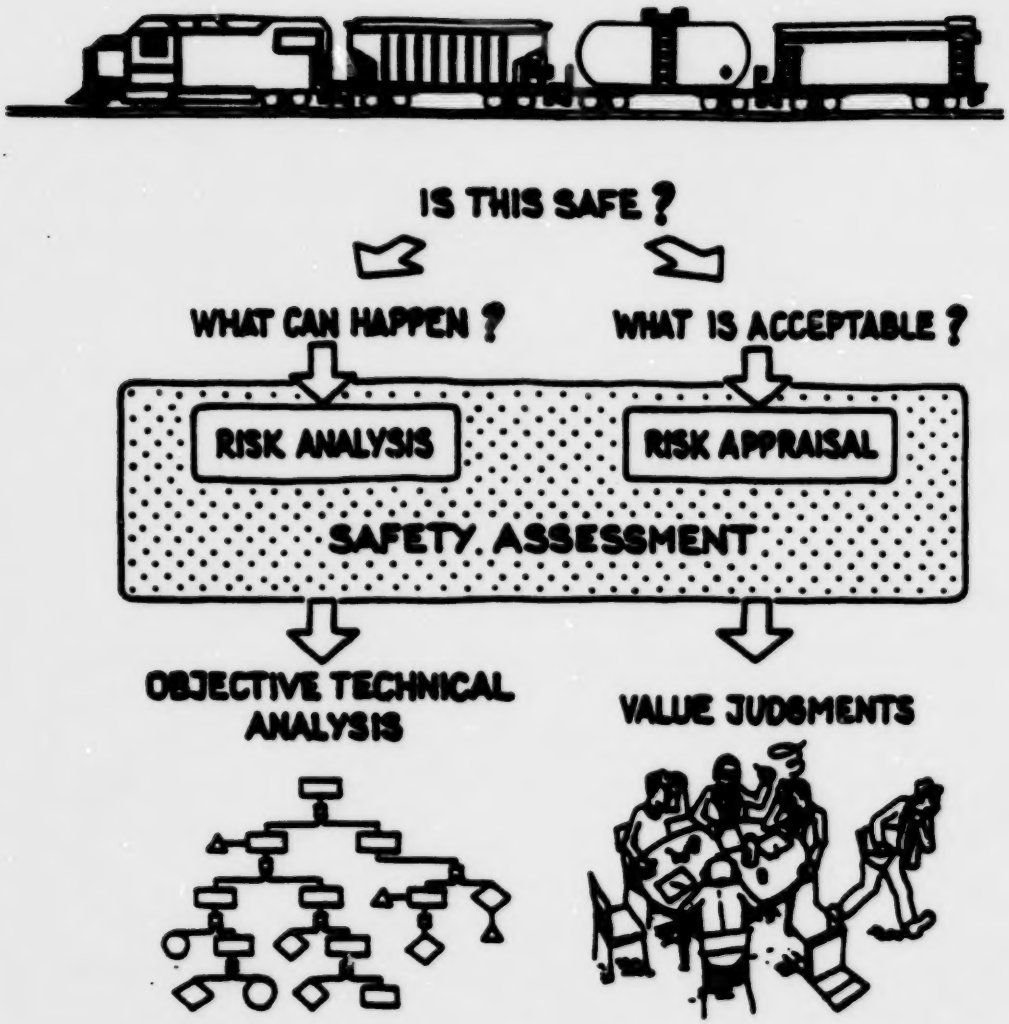
b) Risk Appraisal: judging the acceptability of risks – a matter of personal and social value-judgement (a normative, political activity).

Thus, estimates of risk are the outputs of a scientific effort and they become the inputs to personal and social decision-making.

In this report, "risk" is used in the context of measurement of the frequency (probability) of occurrence of a hazardous event, and of the consequences of that event. This may be expressed formally as:

$$\text{Risk} = \text{Frequency} \times \text{Consequences}$$

FIGURE 1.1



THE DIVISION OF THE SAFETY PROBLEM INTO THE TECHNICAL RISK ANALYSIS AND THE RISK APPRAISAL

Adapted From: Bohnenblust and Schneider (1984).

The mode or units used to express risk vary, e.g.:

- fatalities per annum;
- probability of fatality for an individual in a given time period; and
- probability of multiple fatalities during a specified time period for a given exposed population.

Another aspect of risk is that of whether the consequences are immediate (acute) or delayed (chronic). Concern in this report is with death that effects of the hazard are fully manifest within the duration of the event. The reasons for this approach are:

- Death is a more definitive effect while injury covers a wide spectrum of effects that are not easily quantifiable.
- Different hazards cause different sub-lethal physiological effects to humans. Summation of risks of injury as a measure of absolute risk is not only very difficult, but the dose-response data for sub-lethal effects are generally not available.
- It provides a basis for comparison with other commonly encountered risks, for which historical data in the form of recorded deaths are available.
- Death has been chosen as a measure for all major risk assessment studies that have been reviewed.

While the estimates of risk provided in this study deal only with the risks of immediate fatalities resulting from potential accidents, it must be understood that

there can also be delayed fatalities and sublethal effects as well as other adverse impacts of accidents such as environmental contamination and property damage.

We must understand that there is a diverse range of possibilities. For example, the world's largest toxic chemical disaster at Bhopal, India resulted in a few thousand immediate fatalities and some tens of thousands of people injured by sublethal levels, some of the effects resulting in delayed fatalities. On the other hand, accidents involving fires and explosions can result in immediate fatalities without delayed fatalities or sub-lethal effects. Clearly, the consequences depend on a variety of factors: the nature of the accident; the dangerous goods involved; the accident location; the proximity and density of population; etc. It is not possible, therefore, to simply scale non-lethal risks on the basis of estimated lethal risks and any attempt to do so with the results in this report would be unfounded.

The importance of the foregoing explanation is to provide the reader with some insights into the complexities of the problem as well as to provide some perspective for interpreting the estimates of risk presented later in the report.

There are two principal measures of risk which need to be considered in assessing risks to the public. They are "individual risk" and "societal risk". Individual risk is defined as the frequency of harm to which an individual is exposed from a specific hazard or combination of hazards. In this report, individual risk is expressed as the probability of death per year for an exposed individual. As an example, the individual risk of death due to smoking for an individual smoker is about 1 chance in 330 per year.

Societal risk is defined as the frequency of harm to either a societal group or the public at large who are exposed to a specific hazard or combination of hazards. In this report, societal risk is expressed as the number of estimated fatalities in a specified period of time, in an exposed group.

The values of societal risk may be expressed as either the estimated number of fatalities per incident, or as estimated number of fatalities per averaged year. The inverse of the latter value (in years per fatality) is used when less than one fatality per year is estimated.

Societal risk for the individual risk example given above can be stated in the following manner: the risk of death from smoking per 1,000,000 persons who smoke is about 3,000 deaths per year.

By using estimates of individual and societal risks, such as those given later in this report, an evaluation can be made of the acceptability of the levels of risk. If the levels of risk are deemed to be acceptable, then no further action is required. If, on the other hand, the levels of risk are considered unacceptable, then risk reduction measures need to be considered. A commonly-used, risk-reduction measure is a buffer zone or set-back distance between a hazardous facility and residential and/or industrial developments. This report provides the City's Planning and Development Department with, in the main, an analysis of the potential reductions in risk that could result from alternative set-back distances as well as the costs associated with implementation of various set-backs.

2.0 STUDY AREA AND FACILITIES INVESTIGATED

The study area is that bounded by the limits of the City, as shown in Figure 2.1. In this section the facilities that have been investigated in this study are described.

The rail corridors and associated traffic patterns which have been analyzed in the quantitative assessment of risk to the public are described first. This is followed by a qualitative discussion of fixed hazardous facilities (i.e., industrial plants that handle DGs) that are located near rail corridors, and that could be impacted by a rail accident. Potentially such events could lead to a release of DGs (i.e., knock-on effect). Then, a discussion is given of public facilities in the vicinity of rail corridors which have been identified as areas of key concern since they are particularly prone to risk (e.g., schools, senior citizens residences).

2.1 RAIL CORRIDORS AND TRAFFIC PATTERNS

The existing rail infrastructure consists of four mainline rail corridors. Two of these corridors run east-west and the other two run north-south. A brief description of each corridor is provided below and each is shown on the map of the City, given in Figure 2.1. A legend is provided that shows the segments that make up each rail corridor. In addition to Union Station, which is the central passenger train station, marshalling yards that handle high volumes of DGs are also identified.

Northern East-West Corridor (Corridor I)

This rail corridor consists of the CP North Toronto and Galt subdivisions from Runnymede Road (western city limit) to Moore Park Ravine (eastern city limit). The CP West Toronto marshalling yard is contained in the corridor, just west of Weston Road. This corridor is referred to as the main freight corridor.

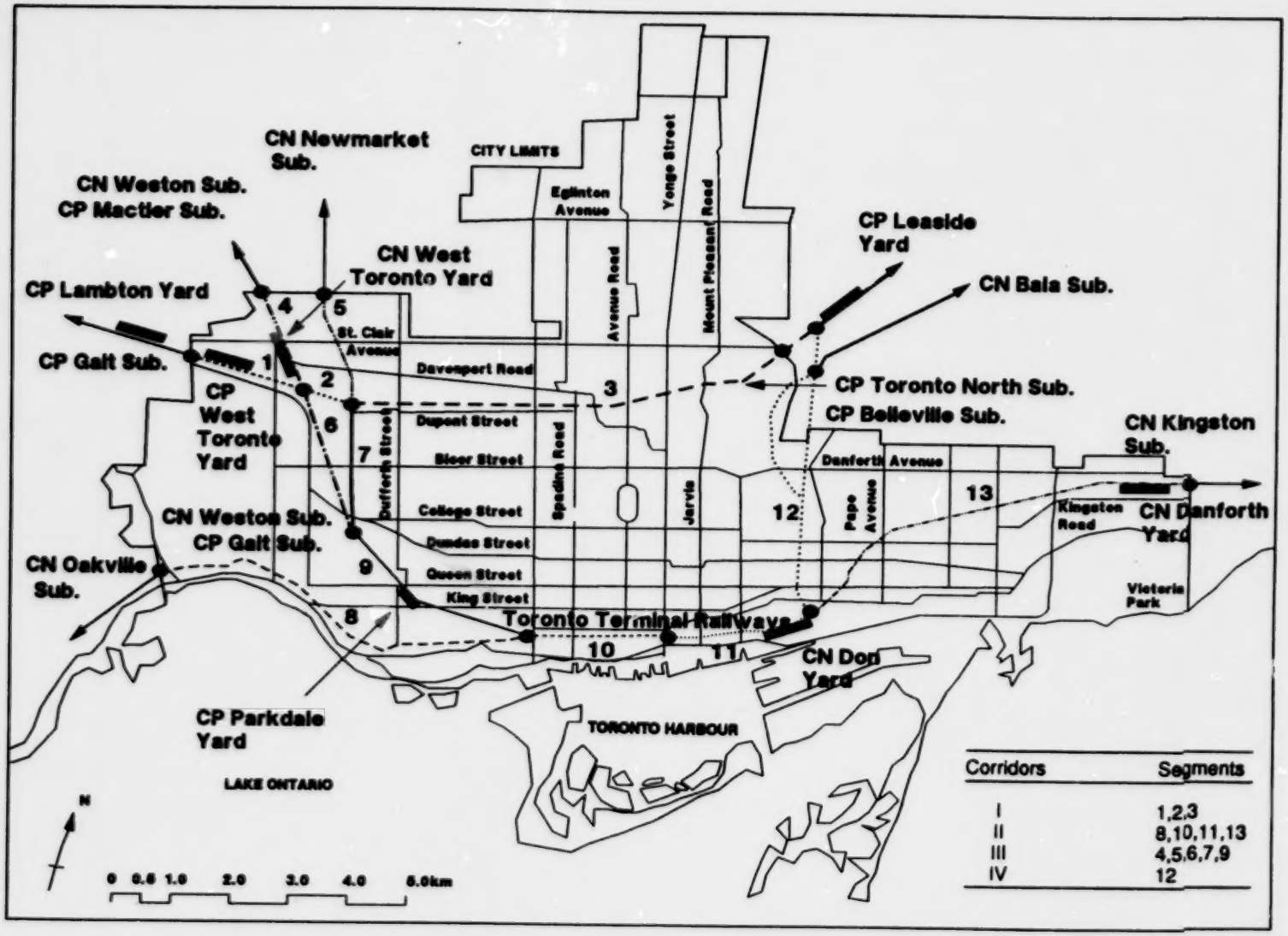


FIGURE 2.1 CITY OF TORONTO STUDY AREA AND RAIL SEGMENTS

Southern East-West Corridor (Corridor II)

This rail corridor consists of the CN Oakville and Kingston subdivisions and the Toronto Terminals Railway, from the Humber River (western city limit) to Victoria Park Avenue (eastern city limit). This corridor contains Union Station, which is located at Bay Street, and the CN Don marshalling yard which is located near the junction of the Gardiner Expressway and the Don Valley Parkway. This corridor is referred to as the main passenger corridor.

Western North-South corridor (Corridor III)

This rail corridor consists of the CN Weston and Newmarket subdivisions as well as the CP Galt and MacTier subdivisions. The southern limit is at Bathurst Street. The corridor follows a northwest path from Bathurst Street and as it crosses Dundas Street, the Newmarket subdivision begins to travel directly north, while the CN Weston, MacTier and Galt subdivisions continue on a northwest route to Lavender Road.

Eastern North-South Corridor (Corridor IV)

This rail corridor consists of the CN Bala and CP Belleville subdivisions from the junction of the Gardiner Expressway and Don Valley Parkway to about 500 m north of Danforth Avenue (city limit). The corridor follows the Don River, with the two subdivisions separating and following opposite banks of the river north of Winchester Street.

The main emphasis in this study is on Corridor I (main freight corridor). Of secondary interest is Corridor II (main passenger corridor). The other two corridors will not be considered in any detailed manner other than being included in the overall baseline risk estimates.

For the existing rail system, a general description of rail movements is provided in Table 2.1. This table shows the breakdown of traffic by corridor, as well as by the uniform accident environment (UAE) segments within each corridor. UAE refers to sections of the rail corridor that exhibit similar accident frequencies due to similar track characteristics, speed and signalling systems. In this table, dangerous goods are classified by the rail companies into the groups listed below. It will be noted that this classification scheme differs from the classification of dangerous goods in the Transportation of Dangerous Goods Regulations. These groupings are used here for reporting purposes only and not in the detailed risk assessment (see next section).

- Special Dangerous Commodities (SDCs): These include explosives, toxic or corrosive gases and liquids, which could cause significant harm beyond the immediate rail right-of-way.

- Dangerous Commodities (DCs): These include substances which, if released, would cause harm primarily within the rail right-of-way.

- Dangerous Mixed Carloads: These are generally boxcars containing some packaged goods which could cause a hazardous situation. The consequences may be worsened by the presence of the other commodities.

- Residue Cars: These are rail tankcars that have carried dangerous goods and still contain a residual amount (less than two percent of the car's original load).

Northern East - West Corridor (Corridor I)

The corridor is the main Canadian Pacific (CP) Railways freight line.

TABLE 2.1

Annual Freight Traffic Along City Rail Corridors

	TOTAL TRAFFIC					LOCAL TRAFFIC				MAINLINE TRAFFIC			
Rail Segment	Length (km)	D.C. Carloads	S.D.C. Carloads	D.C. Mixed	Total Cars	D.C. Carloads	S.D.C. Carloads	D.C. Mixed	Total Cars	D.C. Carloads	S.D.C. Carloads	D.C. Mixed	Total Cars
Corridor I													
1	1.58	2869	4043	16494	596655	1501	902	7779	74966	1367	3141	8715	521689
2	1.02	2129	2763	4693	669692	710	134	0	68533	1419	2629	4693	601159
3	6.91	2129	2763	4693	669692	710	134	0	68533	1419	2629	4693	601159
Corridor III													
4	1.66	1677	1455	12112	260064	1037	906	6562	33419	640	1037	5550	226645
5	2.11	915	108	219	48998	915	108	219	48998	0	0	0	0
6	2.24	495	68	1711	22396	495	68	1705	22396	0	0	6	0
7	1.63	915	108	219	48998	915	108	219	48998	0	0	0	0
9	3.63	631	167	1706	64884	631	167	1706	64884	0	0	0	0
Corridor II													
8	6.46	656	64	206	71729	506	60	206	28543	150	4	0	43186
10	1.76	1288	230	1912	135397	1138	226	1912	92211	150	4	0	43186
11	2.24	1249	217	453	140851	1099	213	453	97665	150	4	0	43186
13	6.77	306	58	887	86379	306	58	887	51051	0	0	0	35328
Corridor IV													
12	3.41	1140	83	1623	63362	1140	83	1623	62195	0	0	0	1167

Notes:
1. D.C. refers to Dangerous Commodity.
2. S.D.C. refers to Special Dangerous Commodity.
3. Sources and dates of data:
   a) CP rail lines - CP provided 1986 traffic flows which changed from 1985.
   b) CN rail lines - CN originally provided 1985 traffic flows as given in IBI (1987).

Corridors:
Corridor I: Northern East-West Corridor
Corridor II: Southern East-West Corridor
Corridor III: Western North-South Corridor
Corridor IV: Eastern North-South Corridor

The yearly freight movements along this corridor exceed those in the other corridors by a factor of 5 to 10. The majority of bulk traffic, including dangerous goods (DG) traffic and total freight traffic is through traffic (i.e., it neither originates from, nor is destined to the Greater Metropolitan Toronto Area) (Concord, 1987).

The fixed facilities investigated and utilized for the detailed risk assessment are exposed to segments 2 and 3 of the main freight corridor (see Figure 2.1). The basis of this selection is the high DG traffic along the main freight corridor and the proximity of these facilities to the corridor.

Southern East - West Corridor (Corridor II)

This corridor is the main passenger train corridor through the City of Toronto; Union Station is contained within this corridor. In addition, some freight traffic also moves through the corridor, which includes a small volume of DG traffic.

2.2 FIXED HAZARDOUS FACILITIES

Industrial facilities located near rail lines which handle DGs could be involved in a rail accident leading potentially to an escalation of the consequences of the accident if DGs at the facility are released. Due to the potential for this so-called "knock-on effect" such facilities were investigated.

The City provided a list of the facilities to be examined which is given in Table 2.2. The Welders Supply Co. was added to the City's list after a site visit along the main freight corridor. The investigation initially consisted of obtaining information pertaining to each facility on the following list of features as provided through the cooperation of some of the companies:

TABLE 2.2

Industrial Facilities

1.	National Rubber* Cawthra Facility 35 Cawthra Avenue
2.	National Rubber* Symington Facility 386 Symington Avenue
3.	BASF Inmont Canada Limited* 1444 Dupont Street
4.	Welders Supply Company* 1 Poplar Plains Road
5.	Nacan Products Limited 371 Wallace Avenue
6.	Glidden Paint and Wallpaper 349-351 Wallace Avenue
7.	Viceroy Rubber and Plastics 1655 Dupont Avenue
8.	Anchor Cap and Closure 275 Wallace Avenue
9.	TTC Hillcrest Unit* 1138 Bathurst Street

* Denote facilities selected as representative industrial land-use facilities involving DGs along the main freight corridor.

- types and quantities of DGs handled on-site;
- location (plot plans) of stores of DGs on-site, particularly in relation to rail lines;
- physical features of site and surrounding lands; and
- number of employees.

Site visits were made and where it was not possible to gain entry to the plant site, external observations were made.

The objectives in assembling this information are as follows:

1. To identify industrial facilities where rail accidents could potentially have "knock-on effects".
2. To examine and present, in qualitative terms, the potential consequences of "knock-on effects" at these facilities.
3. To select some of these facilities as being representative of industrial land-use for valuation of the lands with respect to possible set-back distances.
4. To utilize detailed population data in the area of such facilities for the quantitative estimates of risk from rail accidents.

A discussion pertaining to the above on each of the facilities listed in Table 2.2 follows. The locations of these facilities are given in Figure 2.2. Those facilities selected as being representative of industrial land-use involving DGs are noted by an asterisk in Table 2.2. It should be noted that only a qualitative discussion is

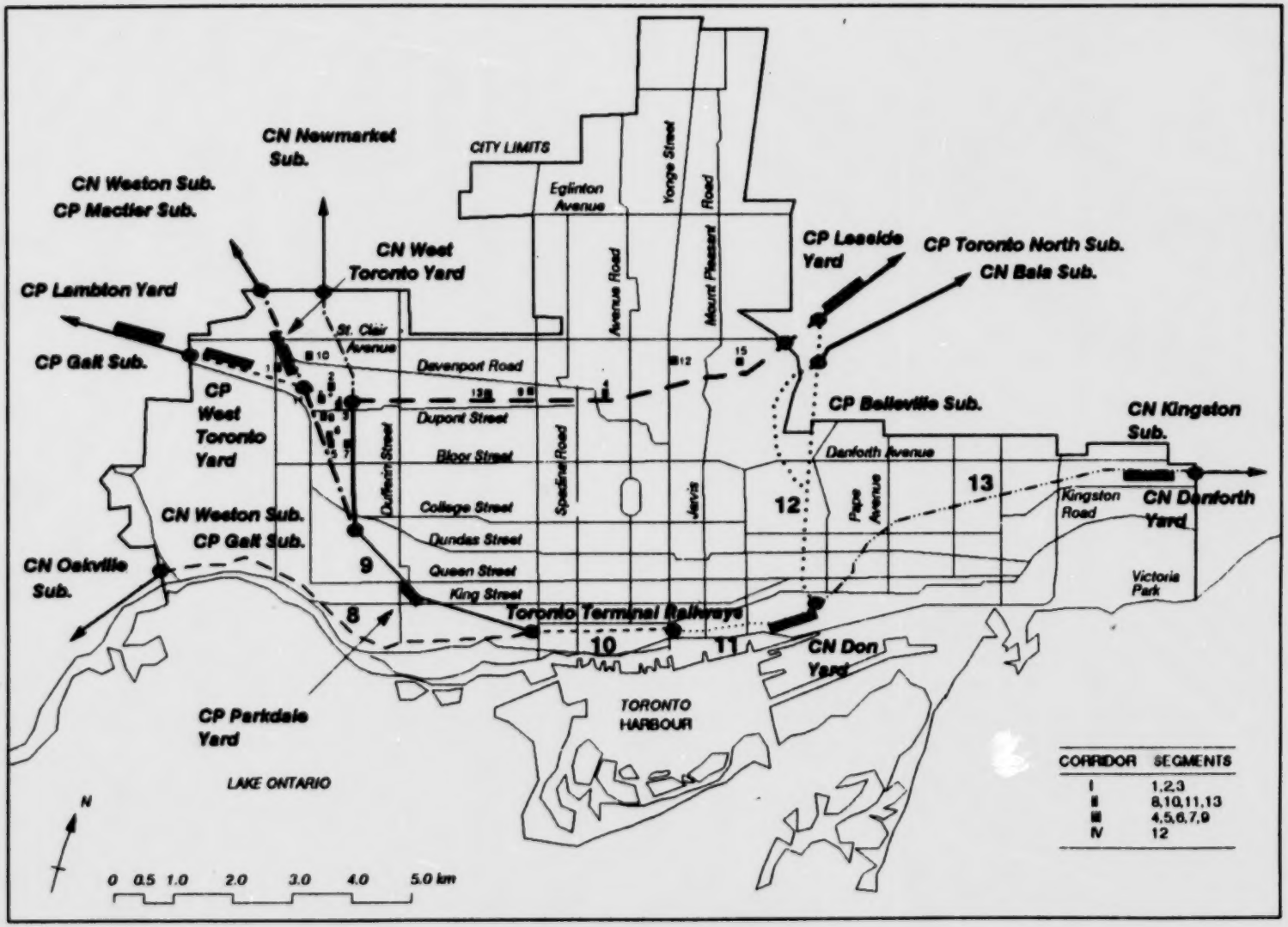


FIGURE 2.2 Locations of Fixed Facilities along Main Freight Corridor

presented on the risks associated with these facilities. A quantitative risk analysis for each facility was not part of the scope of this project. Also, to conduct such analysis would require considerably more information and data than were available for this study and it would necessitate the full cooperation of the owners of each of the facilities.

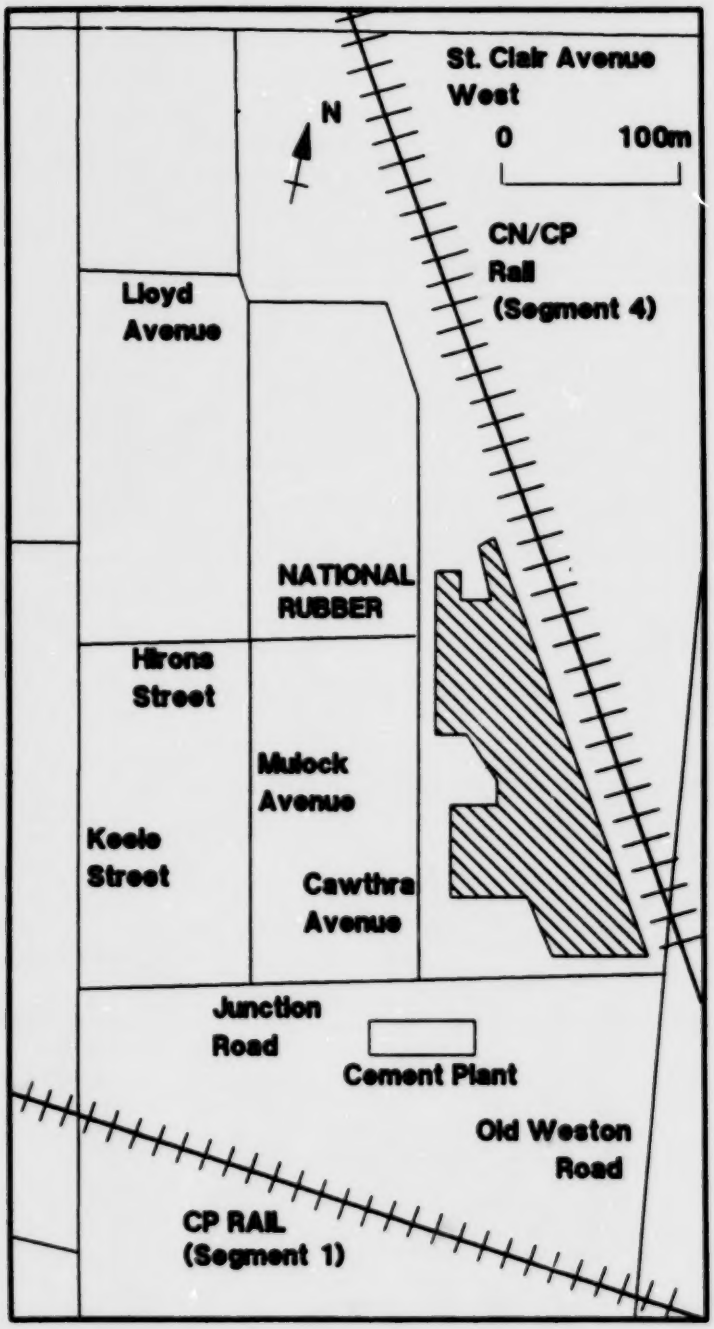
Substantial effort was made by the project team to obtain data on the dangerous goods stored and handled at the facilities listed in Table 2.2. The general unavailability of these data meant that a quantitative assessment was not possible. The City should pursue avenues to obtain the necessary data to establish a city-wide data base on major industrial hazards to which the public are exposed. Also, the City should give consideration to having quantitative estimates made of the risks to the public associated with fixed facilities.

NATIONAL RUBBER - CAWTHRA FACILITY

This National Rubber facility is located at 35 Cawthra Avenue. Location of the facility is shown in relation to the rail lines in Figure 2.3. It is situated on the west side of the rail line (CN Weston/CP Mactier Subdivision, Segment 4) and north of Junction Road. The number of employees at the facility is 110. An old spur is found on the west side of the facility but it is not known if it is still in use. A cement plant is located directly south of the facility on Junction Road. The general area is industrial. The raw feed material was observed on the front of the facility. The topography of the surrounding area is flat and it is a developed area. The facility is located adjacent to the rail property or rail right-of-way. Rubber is a solid product which is combustible and could contribute significantly to a fire. Copious amounts of black smoke would be expected during a fire.

FIGURE 2.3

National Rubber - Cawthra Facility



A visit to the facility lead to the following observations and reasons relating to the vulnerability of the facility to the effects of rail accident:

- there is little buffer zone protection offered by distance between the rail line and the facility;

- the facility could be vulnerable to collision by train, i.e., no barricade protection offered by the present layout;

- total destruction would be possible by blast effects of an explosion, due to a small set-back;

- there is a flammable drum storage area (Atlas Drum) located across the rail lines to the southeast of the facility which could become involved in a fire situation given a rail accident;

- toxic hazards due to a chlorine or ammonia release would present a serious lethal hazard to the personnel on the facility site;

- fireballs would present a serious thermal radiation hazard to the personnel and to the facility. The whole facility would likely become consumed in a fireball from a propane tankcar accident. A level of 90% lethality is expected within 170 m from the release point of propane;

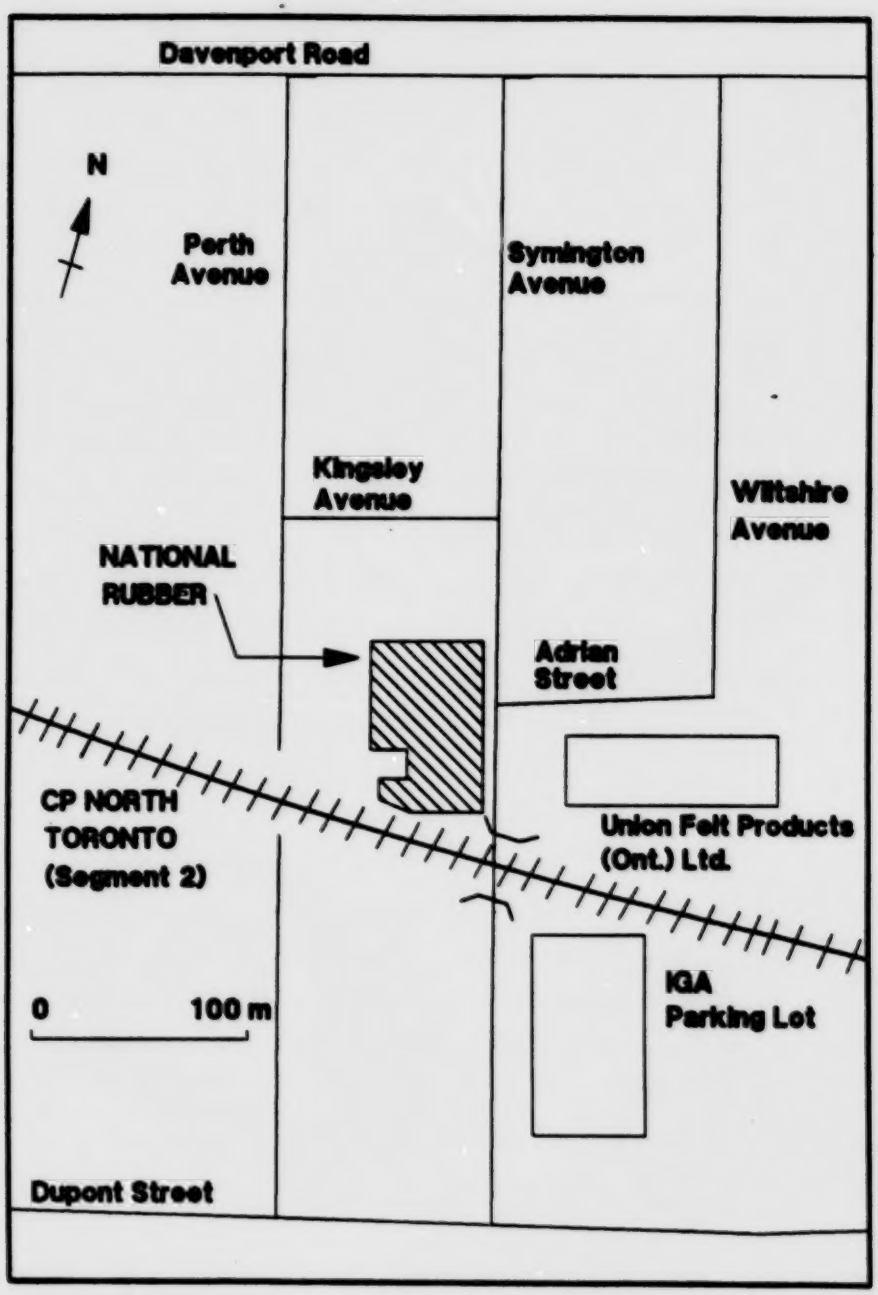
During the survey by the project team, no detailed information could be obtained for the materials used at the plant.

NATIONAL RUBBER - SYMINGTON FACILITY

The second National Rubber facility is located at 386 Symington Avenue. Location of the facility is shown in Figure 2.4. The rail line is located directly

FIGURE 2.4

National Rubber - Symington Facility



south of the facility and presents a significant hazard to the facility due to its close proximity. There are 229 employees at this facility. A rail overpass is located to the southeast of the facility which passes over Symington Avenue. Symington Avenue slopes down southwards in front of the facility and up towards Dupont Avenue. There is a flammable drum storage in a yard located to the south of the facility and north of the rail line. The nearest industrial neighbour is Union Felt Products (Ont.) Limited. Residential areas are located to the north of the facility along Symington and Kingsley Avenue and south of Dupont. A shopping plaza is located on Symington southeast of the facility. The BASF Inmont facility is located about 130 m southeast of the National Rubber facility (not shown on layout).

The following observations were made during the site visit; in most cases they indicate the vulnerability of the facility:

- the set-back is insufficient to minimize the effects of a rail accident;

- no large storage areas were noted for flammable materials which could be susceptible to accidents and possible knock-on effects;

- the dip in the road could act as a collection basin for flammable liquids or heavy gas released from a rail accident. This would localize the hazard near the facility. Drainage of the released material (i.e., propane or gasoline) in the dip is possible; thus explosion hazards are possible in the sewer system. This could make escape of personnel difficult at the front of the plant. These comments apply to an accident that occurs near the overpass; and

- the facility is located at an elevation slightly lower than that of the rail line.

The following hazards could significantly impact the facility:

- blast effects of explosion of flammable substances on the facility construction could result in building collapse;
- thermal radiation loads from fireball on the surrounding area;
- chlorine releases and the toxic hazards to the personnel; and
- physical impact considerations are likely due to the present elevation of the rail line. Collision with the facility is a real possibility but comment on any potential resulting hazardous events is not possible due to inadequate knowledge about the internal layout of the plant.

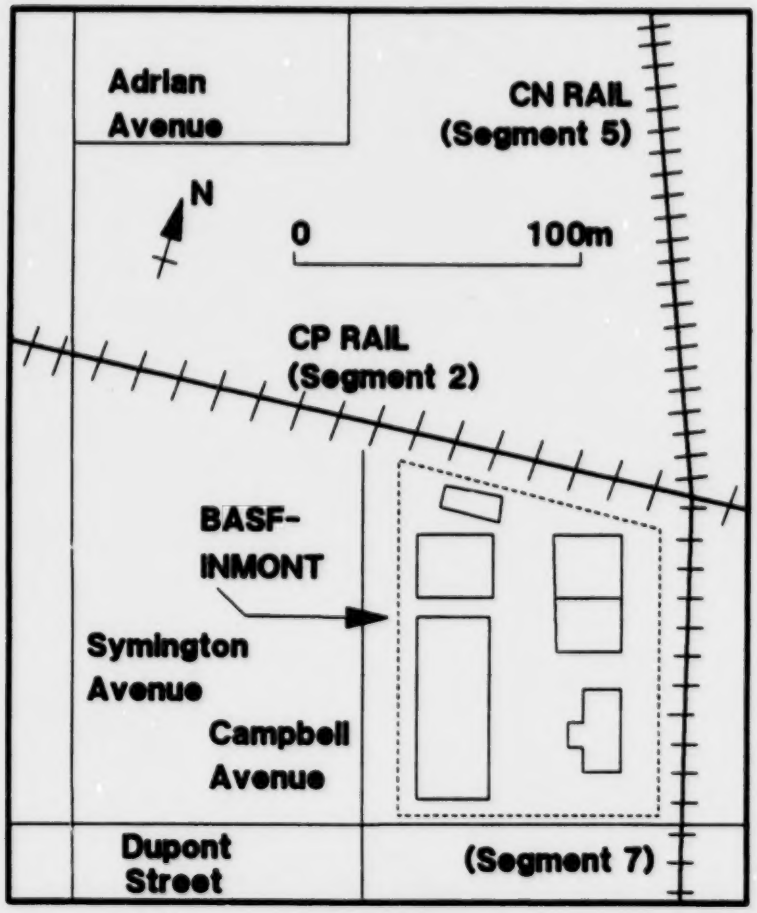
A dangerous goods accident near the National Rubber facility could cause high lethality and serious property damage.

BASF INMONT CANADA INC.

The BASF Inmont Canada Inc. facility is located at 1444 Dupont Street and is an example of a coatings/paint plant. Location of the facility is shown in Figure 2.5. The National Rubber facility is located northwest of the facility. The Inmont facility is located adjacent to the rail line. The rail line is above the factory level. The CP North Toronto subdivision is located directly north and the CN Weston/CP Galt subdivision is located directly east of the facility. The facility is therefore exposed to risk from the rail lines on two flanks compared to the more usual situation of rail lines at one side of the perimeter. Unloading of flammable materials from tank trucks occurs at the north end of the facility adjacent to the CP rail line. A nitrocellulose storage area is located at the east side of the facility. Nitrocellulose is a highly flammable and explosive material and poses an additional hazard in the event of a rail accident. The materials used

FIGURE 2.5

BASF Inmont Canada Inc.



at the facility are flammable liquids such as solvents and resins. A flammable liquid drum storage is located at the north end of the plant. The facility has 18 underground storage tanks. The facility has a total of 120 employees. There are residential houses located on Campbell Avenue.

The BASF facility is vulnerable to the effects of a rail accident. A DG accident could cause serious damage to the property and high lethality to the plant personnel and surrounding population. The additional comments below relate to interaction of a rail accident and the specific layout of this facility. The comments illustrate the vulnerability of this facility and potential knock-on effects which could further increase risk to the surrounding population.

- the flammable drum storage could be involved in a fire situation which could result in missiles;

- the knock-on effects from involvement of the nitrocellulose storage area could cause serious blast effects from an explosion; and

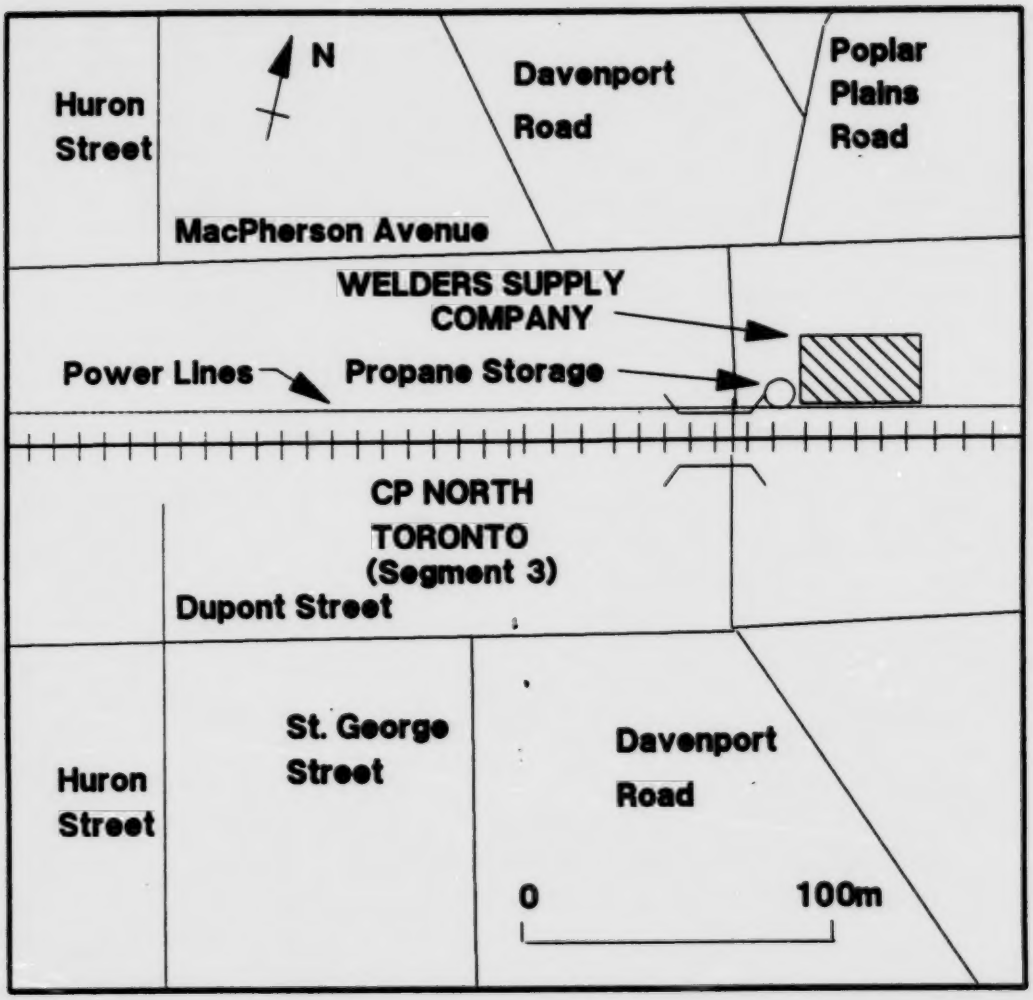
- a derailed train travelling into the plant area could interact with various items of plant, for example, a train could impact an underground storage tank causing a tank fire or impact a flammable liquid truck.

WELDERS SUPPLY COMPANY

The Welders Supply Company located at the intersection of Davenport Road and MacPherson Avenue (1 Poplar Plains Road) has a propane filling station. Location of the facility is shown in Figure 2.6. The rail line is elevated above the facility level. An underpass (i.e., Davenport) is located to the west of the facility and the possibility exists for noxious or flammable materials to enter the drainage. The vertical propane storage vessel is located adjacent to the rail line with a small set-back distance and is exposed directly to physical impact by a derailed train.

FIGURE 2.6

Welders Supply Company



Hydro wires run parallel to the railway on the north side and could potentially be impacted by a derailment, which would complicate firefighting or other rescue operations after a rail incident. A major escalation of events could result given a rail accident and the involvement of the propane bullet. The risk posed by this facility is higher than most of the other facilities considered due to the land-based storage of propane.

This facility is an example of service areas storing propane on-site which could be vulnerable to events on the rail line. Due to the relatively small set-back distance to the main freight corridor, high lethality and property damage would be expected given a DG accident.

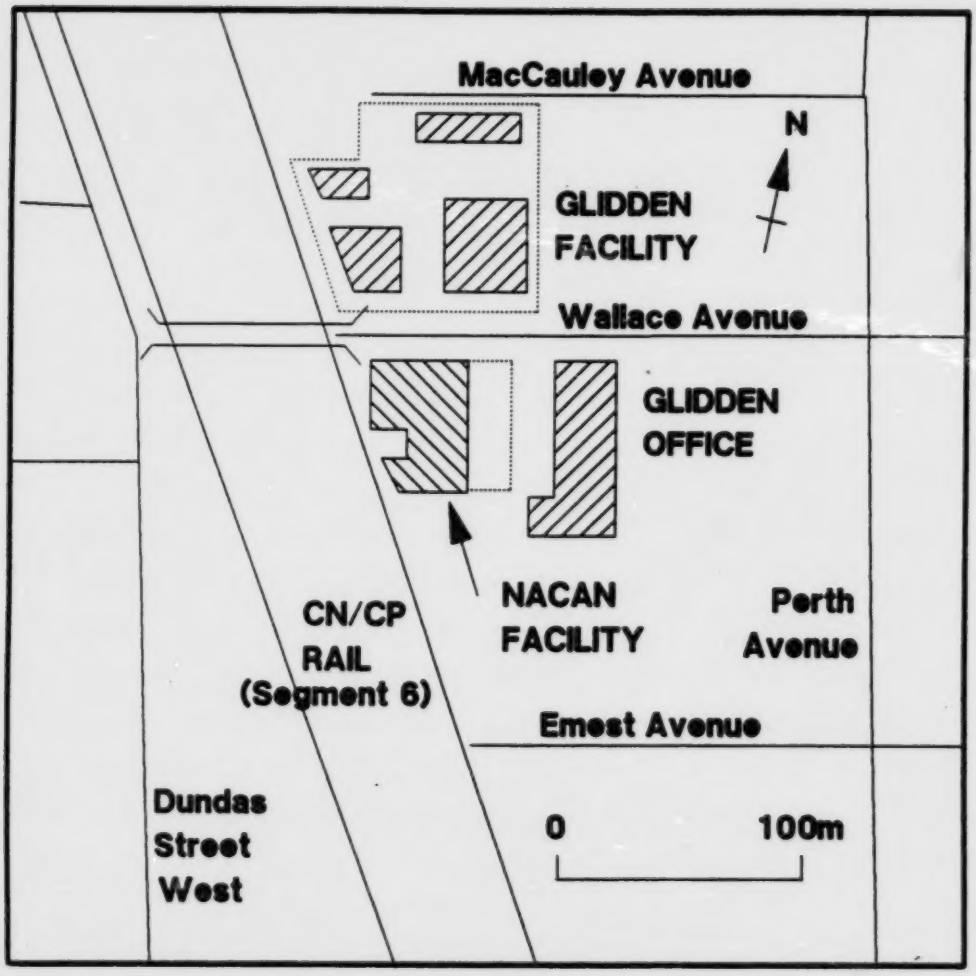
NACAN PRODUCTS LIMITED

Nacan Products Limited is located at 371 Wallace Avenue. Location of the facility is shown in Figure 2.7. The plant produces water-based adhesives which are packaged in 200 L drums and 20 L pails. Quantities of strong acid and aqueous ammonia are stored approximately 180 m from the CP rail tracks inside the building. Approximate separations supplied by Nacan include: (i) nearest track is ca. 9 m to plant building; (ii) the middle track is ca. 90 m from the plant building; and (iii) the middle track is 150 to 180 m from the storage location. There are 14 people employed at this location. The nearest industrial facility is Glidden located directly north of Nacan. There are two sets of rail tracks (i.e., west - three lines, and east - two lines with spurs). The general topography can be described as a flat level area.

The facility could experience the effects of a chlorine release on the main freight corridor but it is not exposed to effects of thermal radiation in any significant way for accidents on this corridor. Nacan is still exposed to the potential risk of a DG accident on the CN/CP rail corridor designated as segment 6. The facility is located relatively close to the rail line and serious loss potential (property and

FIGURE 2.7

Nacan Products Limited & Glidden Paint and Wallpaper



people) would be expected following a rail accident.

GLIDDEN PAINT AND WALLPAPER

Glidden Paint and Wallpaper is located at 349-351 Wallace Avenue. Location of the facility is shown in Figure 2.8. The plant is situated on the north side of Wallace and to the east side of the rail line (CP Mactier/CN Weston Subdivision, Segment 6). No information could be obtained on the dangerous goods used at the facility but external viewing of the facility provided the following observations:

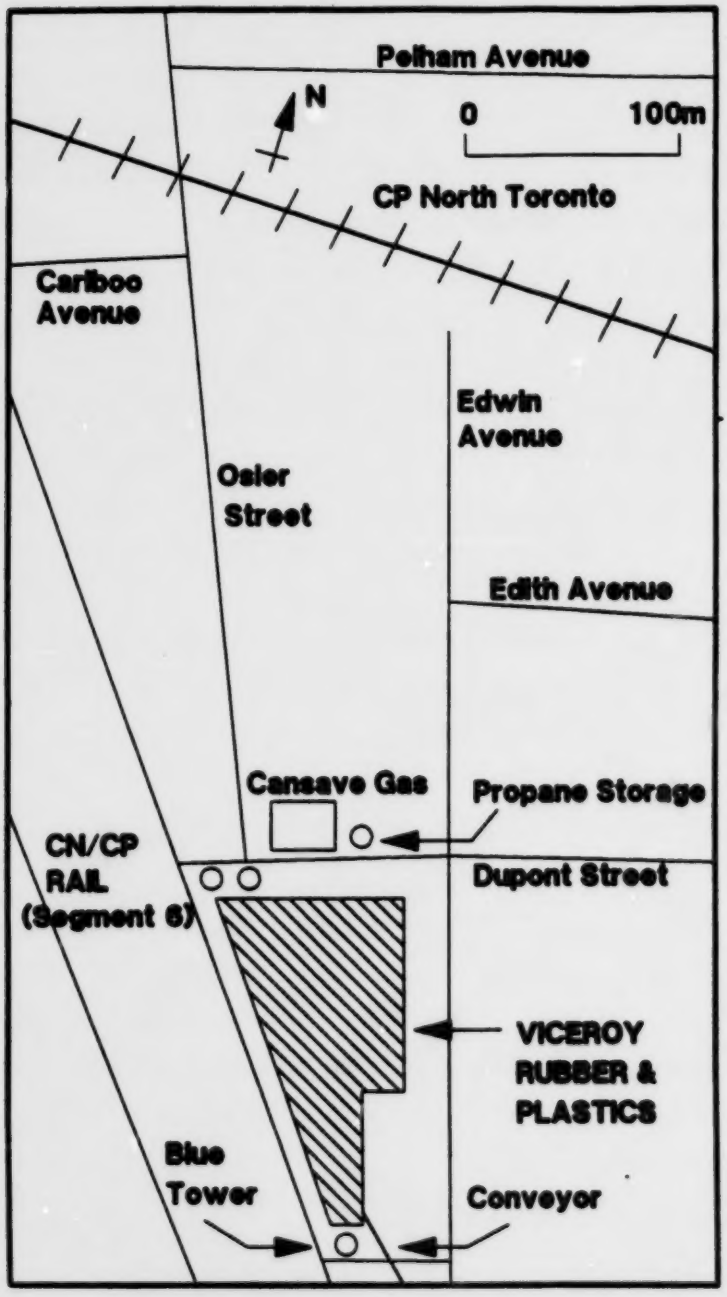
- a flammable liquid drum storage is located in an open storage area north of the plant;
- a loading/unloading rack for truck systems;
- a tall wall is located at the north east building, the use of which is not known. The approximate height is four to five storeys high. It could be a drying tower or a wash tower.

The Glidden office is located on the south side of Wallace. There are 100 people employed at this facility.

The facility is located close to segment 6 (CN/CP rail corridor) and would be exposed to the direct effects of DG accidents on the rail line. The flammable liquid drum storage in the yard and the loading rack could become involved in a fire situation produced by a rail accident. This would complicate fire fighting operations in the area.

FIGURE 2.8

Viceroy Rubber & Plastics



VICEROY RUBBER AND PLASTICS

The Viceroy Rubber and Plastics facility is located at 1655 Dupont Avenue. Location of the facility is shown in Figure 2.8. No detailed information could be obtained of the facility or of the materials produced or handled. The site was externally viewed but due to lack of knowledge, no comments can be made on the hazards that may or may not be present on site. The facility is a large one. It is located east of the rail line (CN Weston/CP Mactier Subdivision, Segment 6) and about 325 m from the main freight corridor. There are four towers that are worthy of note:

- two green towers located to the north west of the facility;
- blue tower located to the south west corner of the facility; and
- white tower located south of the main plant building and west of the power plant.

There are approximately 63 employees at this facility. The CANSAVE gas station has a vertical propane bullet located in close proximity to the north of the main plant. This bullet could be become involved in knock-on effects in the event of a rail accident.

The facility is susceptible to the effects of a rail accident. Accidents on the CN/CP rail corridor located east of the facility would cause serious damage and lethality. The effects of a rail accident on the main freight corridor would be felt to a much lesser extent than at other facilities due to Viceroy's comparatively larger distance to this corridor. However, it should be noted that the level crossing of the CP North Toronto line and Osler Street is a potential source of accidents due to the volume of pedestrian and automobile traffic, which contribute to area risk levels.

ANCHOR CAP AND CLOSURE

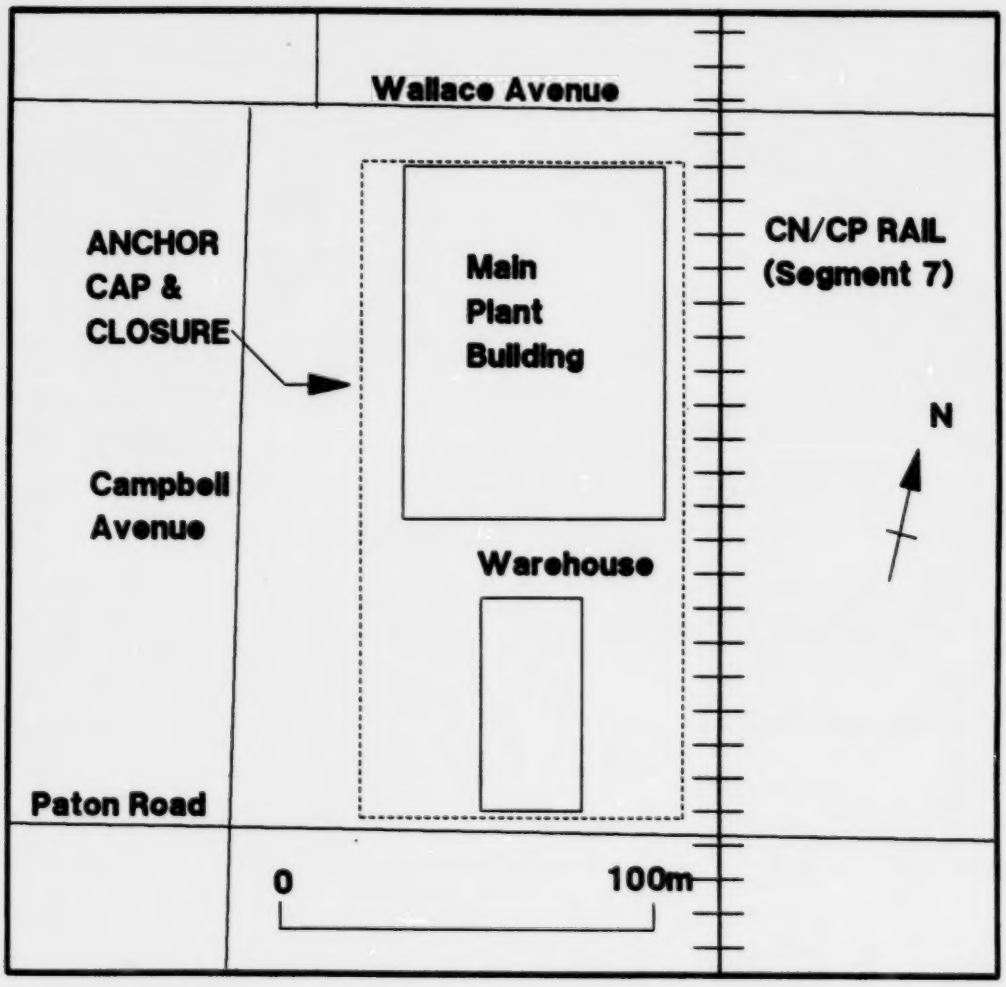
Anchor Cap and Closure is located at 275 Wallace Avenue (intersection of Wallace and Campbell). Location of the facility is shown in Figure 2.9. The CN Weston/CP Galt Subdivision, (Segment 7) is east of the facility. There is a rail spur found on the east side of the plant; the spur is used for the collection of scrap material. There are two buildings on-site: main plant building and a two storey warehouse. A flammable liquid storage area with spill containment is found at the west side of the plant for ca. 80 drums; these include a wide variety of materials including lacquer, thinners, MEK, mineral spirits and acetone. Propane, oxygen, and acetylene cylinders are stored at the southwest corner of the plant. The number of people employed at the facility is 257 people. PCB-filled components in sealed drums are stored near the transformer compound. There is 2100 L of transformer fluid stored near the transformer.

Anchor Cap would be exposed to the direct effects of a rail accident along Segment 7. There is a small setback distance between the facility and the rail line. There is still DG traffic that uses this rail corridor thus the potential risk of flammable and toxic hazards from DG-related accidents exists. There could be extensive loss to property and personnel in the event of a DG accident.Physical impact with a derailed train remains a possibility given the small set back distance. The involvement of the flammable storage would likely result in a fire situation given a rail accident. The facility is vulnerable to the effects of a rail accident.

This facility is exposed to transport risks from segments 7, 6 and, to a much lesser extent from the main freight corridor.

FIGURE 2.9

Anchor Cap & Closure



TTC HILLCREST UNIT

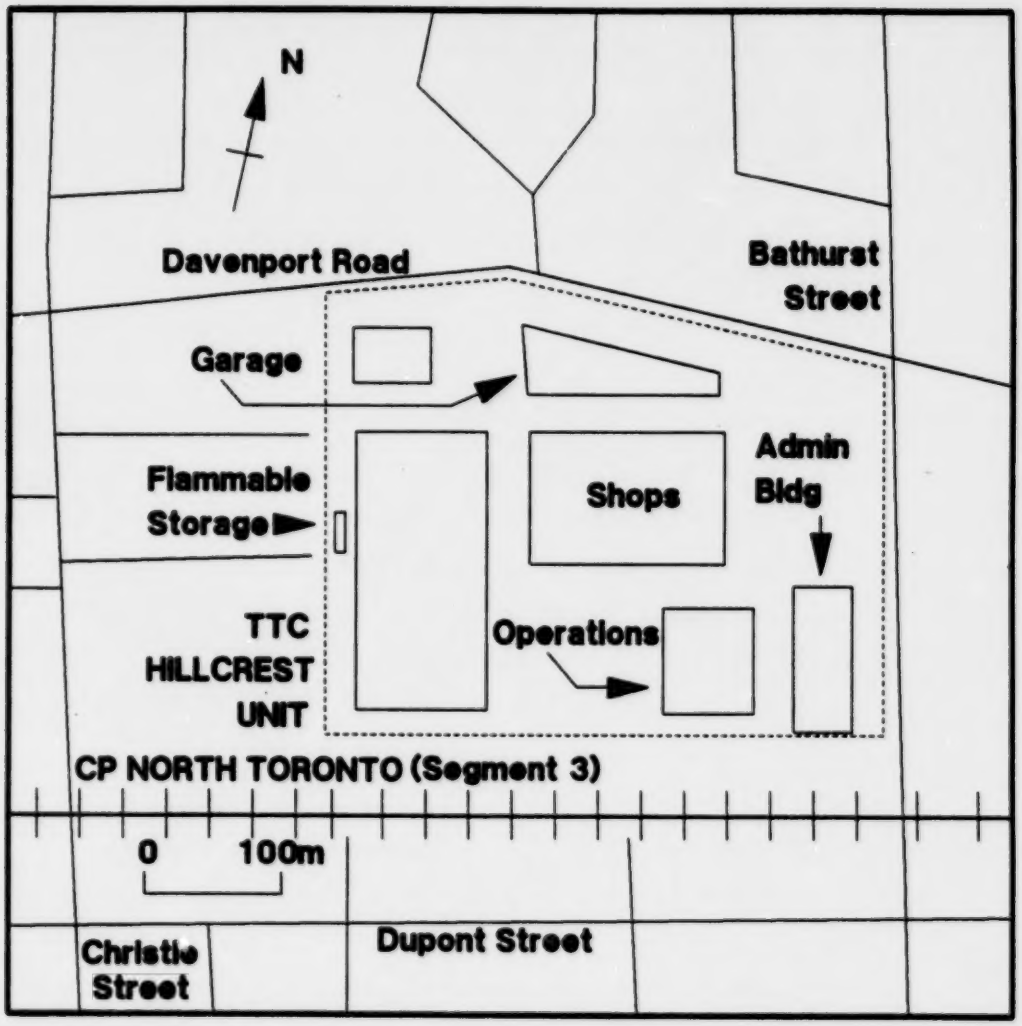
The TTC Hillcrest Unit is located at 1138 Bathurst Street and its location is shown in Figure 2.10. The facility contains a large building and garage for the maintenance of bus vehicles. The administration building is at the southeast corner of the facility and the estimated set-back distance is 35 m. The combustible liquids stored at this facility include diesel fuel, engine oil and Bunker C oil at various locations in the facility; gasoline is also stored. The main plant storage area is located at the south end of the plant and it is not known what the nature of the storage is. The facility is a critical unit to the operation of the TTC. If the facility was exposed to the effects of a DG rail accident, there could be a major disruption to the continuity of operation of the public transportation system. There is a high employment figure at this facility of 2318 employees. The general topography can be described as flat, very close to the rail line and a general gentle slope upwards to the north. The Bathurst Street rail line underpass is a potential collection point for flammable liquids and heavy gases given a failure of a tank car close to the underpass. This would tend to locallize the hazard close to southeast corner of the Hillcrest Unit site.

The facility is vulnerable to the effects of a rail accident. The administration building could experience major impacts from DG releases. A propane fireball or a chlorine release could cause a high number of deaths at the facility. Secondary fires would likely follow most rail accidents involving flammable liquid storage. It is understood that there are no highly toxic materials at the site.

Of the above facilities, the following were selected, in cooperation with City officials, as being representative of industrial land-uses in the area of the main freight corridor which handle dangerous goods and could potentially be impacted by a rail accident:

- National Rubber - Cawthra Facility;

FIGURE 2.10
TTC Hillcrest Unit



- National Rubber - Symington Facility;
- BASF Inmont Canada Ltd.;
- Welders Supply Company; and
- TTC Hillcrest Unit.

2.3 PUBLIC FACILITIES OF KEY CONCERN

In a risk assessment of a large area, as was conducted previously (Concord, 1987), broadly averaged population densities (e.g., along rail corridors) are generally employed, without consideration of specific facilities. In view of the more specific nature of the present study, public facilities that may be particularly vulnerable to rail accidents, such as schools and senior citizens residences, were investigated.

The City provided a list of the public facilities to be examined, as given in Table 2.3. St. Rita's Catholic School was added to the list after site visits along the main freight corridor. Where possible, the following information was obtained for each public facility: number of occupants; location relative to rail lines; physical features of site and surrounding lands.

The objectives in assembling this information are as follows:

1. To identify public facilities particularly vulnerable to effects of rail accidents.

2. To examine and present, in qualitative terms, the potential consequences of a rail accident near these public facilities.

3. To select some of these facilities as representative of (high density) residential land-use facilities for valuation of land with respect to possible setback distances.

4. To utilize detailed population data in the area of such facilities for quantitative estimates of risk from rail accidents.

A discussion follows pertaining to the factors noted above on each of the facilities list in Table 2.3. The locations of these facilities are given in Figure 2.2. Those facilities selected as representative (high density) residential land-use facilities are noted by an asterisk in Table 2.3.

CARLETON VILLAGE PUBLIC SCHOOL

Carleton Village Public School is located at 2054 Davenport Road at an approximate distance of 200 m from the main freight corridor. Location of the school is shown in Figure 2.11. The school yard is found at the north end of the school. This building has four storeys and there are about 400 students at the school. The school is not subject to direct risk of impact by a train leaving the track. The CN Weston/CP MacTier subdivision (Segment 4) is located to the west of the school (approximately 200 m). The school is located at a substantial distance (i.e., approximately 400 m) from the main freight corridor to the south (Segment 2) compared to some of the other facilities in this study. The school is still at some risk to a toxic release which could cause a high lethality level in the school and the surrounding area.

ST. RITA'S CATHOLIC SCHOOL

This school is located at 178 Edwin Avenue and was identified by the study team during a site visit. Location of the school is shown in Figure 2.12. The Carlton Park is an open playground for the school children. The school is located close to the main freight corridor (Segment 2). The occupancy of the school is 20 staff and 270 children.

TABLE 2.3

Public Facilities of Key Concern

1.	Carleton Village Public School 2054 Davenport Road
2.	St. Rita's Catholic School* 178 Edwin Avenue
3.	The Ports* 1155-1177 Yonge Street
4.	Christie Gardens Apartment and Care* 600-602 Melita Crescent
5.	George Brown College* 146 Kendall Avenue
6.	Whitney Public School 119 Rosedale Height Drive

* Denote facilities selected as representative of (high density) residential land-use facilities.

FIGURE 2.11

Carleton Village Public School

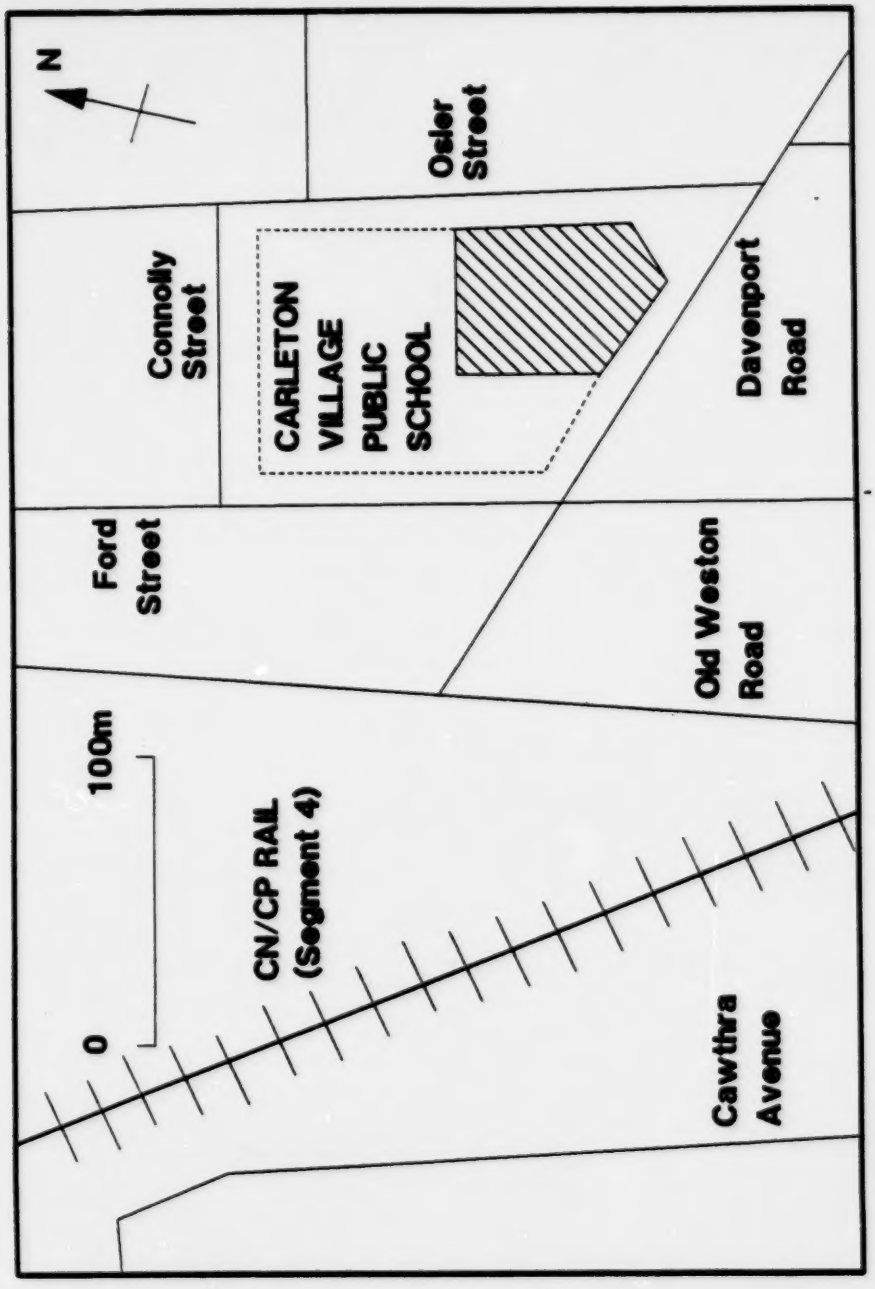
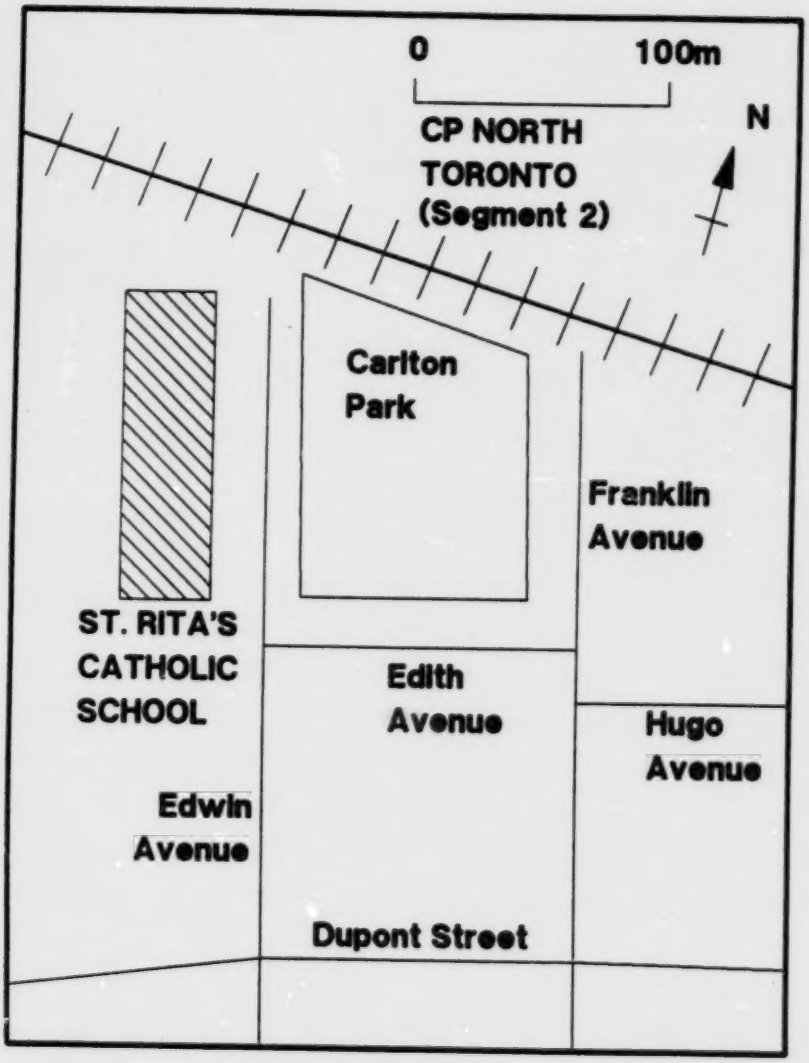


FIGURE 2.12

St. Rita's Catholic School



The general topography is flat and the area is essentially residential. During the site visit, there appeared to be shunting or marshalling of the trains along the rail line. These activities are a matter of concern if they are carried out at this location.

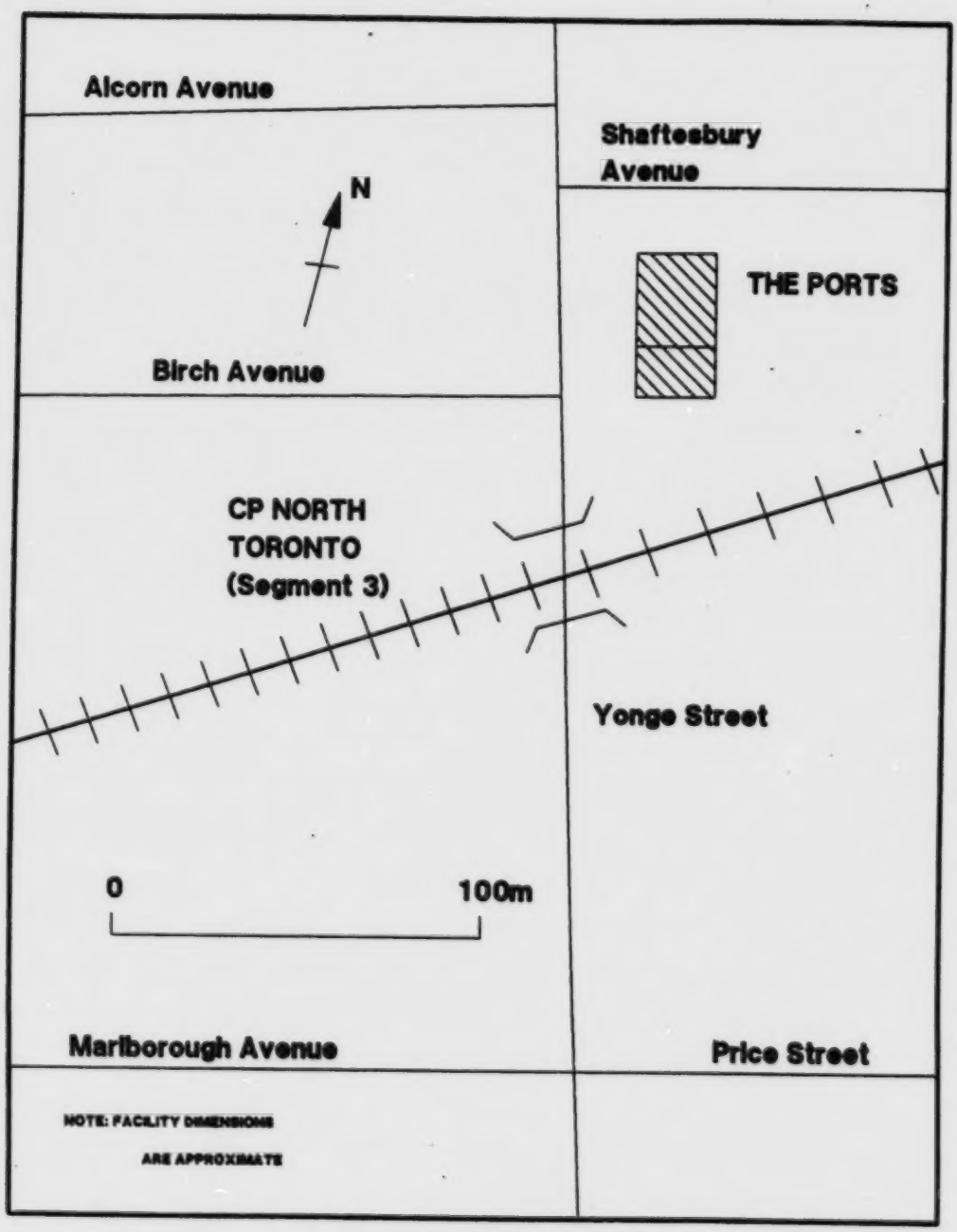
A rail accident in the vicinity of the school could have a significant impact on the school in terms of fatalities and physical damage. There is no barricade protection offered by the present situation. The school and the open playground are vulnerable to the effects of a DG-related accident. A propane fireball taken as an example, would cause high levels of thermal radiation in the immediate surroundings of the school. Other hazards could also have serious consequences at the school.

THE PORTS

The Ports is a set of offices located in two buildings at 1155 Yonge Street (Professional Engineers Building) and 1177 Yonge Street (The Ports). Location of the two buildings is shown in Figure 2.13. The area is typical of a dense, downtown business district with shops and office buildings. The buildings are located on the east side of Yonge Street and directly north of the main freight corridor. The south side of the building is exposed to the rail line. The buildings are seven storeys high with an occupancy of 160 people.

The Professional Engineers building would be exposed to the full effects of a DG-related accident, but offers some barricade protection to the Ports. A chlorine release could cause a high degree of lethality because the area is a busy, downtown district. In the event of a DG-related accident in this area, evacuation of people away from the rail line would pose considerable difficulty due to the high population density of the area. There could also be some risk of physical impact in the event of a high-speed derailment since the tracks are elevated by about two storeys above the base of the buildings.

FIGURE 2.13
The Ports



CHRISTIE GARDENS APARTMENTS AND CARE

Christie Gardens Apartments and Care is a Senior Citizen's Home and is located at 600-602 Melita Crescent. Location of the home is shown in Figure 2.14. The estimated set-back distance to the main freight corridor (Segment 3) is approximately 35 m. Hydro lines run parallel to the rail line on the north side. The apartment is a large facility that encompasses an approximate area that measures 75 x 125 m^2. The number of residents of this building is 300. There is a high population density in the surrounding area which would be exposed to the effects of a rail accident.

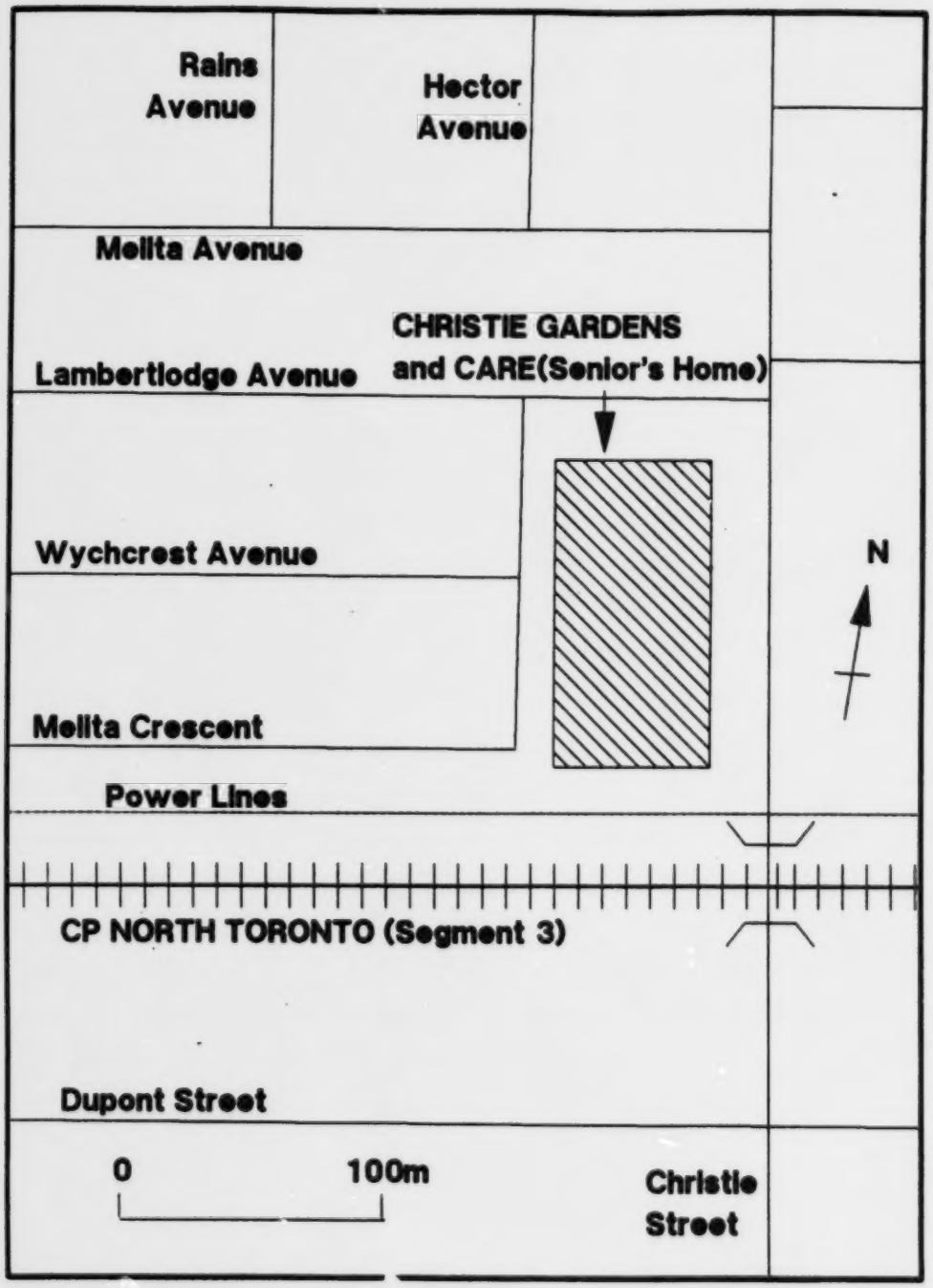
The building is vulnerable to DG-related accidents on the rail line and in this event, there could be high lethality in the building and in the surrounding area. Evacuation of the people in the building would be difficult.

GEORGE BROWN COLLEGE (Casa Loma Campus)

The George Brown College (Casa Loma Campus) is situated between the following roads: Macpherson Avenue (south); Davenport Road (north); Kendall Avenue/Walmer Road (east) and Dartnell Avenue (west). The campus has about 3000 full-time students for most of the year. The full-time enrollment drops to 1,000 students during the summer months. The part-time student population ranges from 2,600 to 4,300 students for most of the year; the corresponding population drops to 1,100 students during the summer. The staff count is about 450 full-time and 350 part-time. The southern end of the campus (at Dartnell/Macpherson) is approximately 44 m from the rail line and the north end of the campus (at Kendall/Davenport) is 194 m. The topography can be described as flat. Location of the facility is shown in Figure 2.15.

FIGURE 2.14

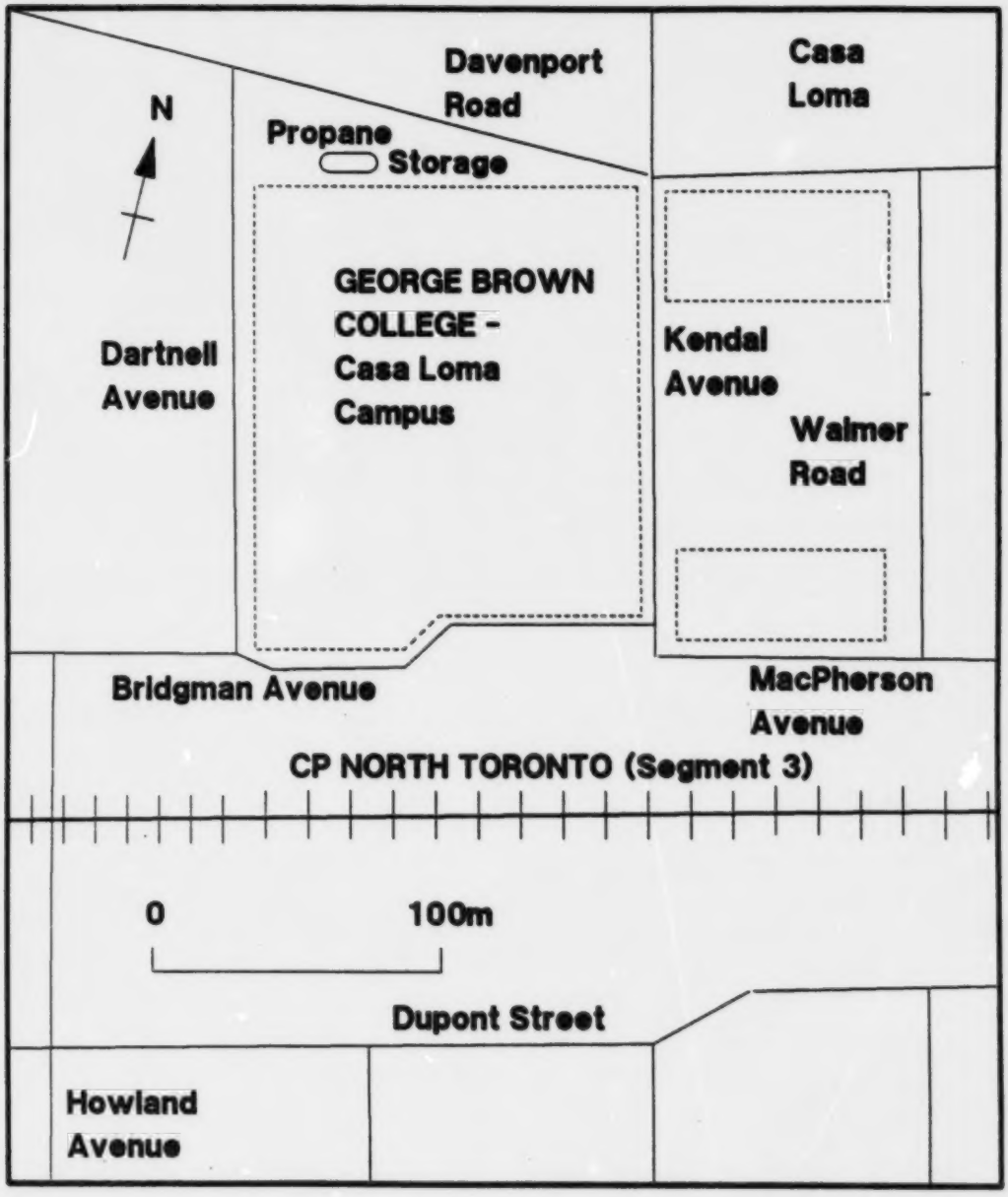
Christie Gardens Apartments and Care



Concord Scientific Corporation

FIGURE 2.15

George Brown College (Casa Loma Campus)



The facility is vulnerable to the effects of a rail accident. The small distance between the buildings and the rail line increases the susceptibility to hazards from DG releases from a rail accident. The campus consists of several buildings. The entire campus could be affected by a rail accident; the southern buildings could be exposed to a higher risk because of their proximity to the rail line. The flat topography at the south end of the school offers no protection against the effects of a rail accident. The college is also likely to store some dangerous goods on site and a rail accident could be escalated by thier presence.

WHITNEY PUBLIC SCHOOL

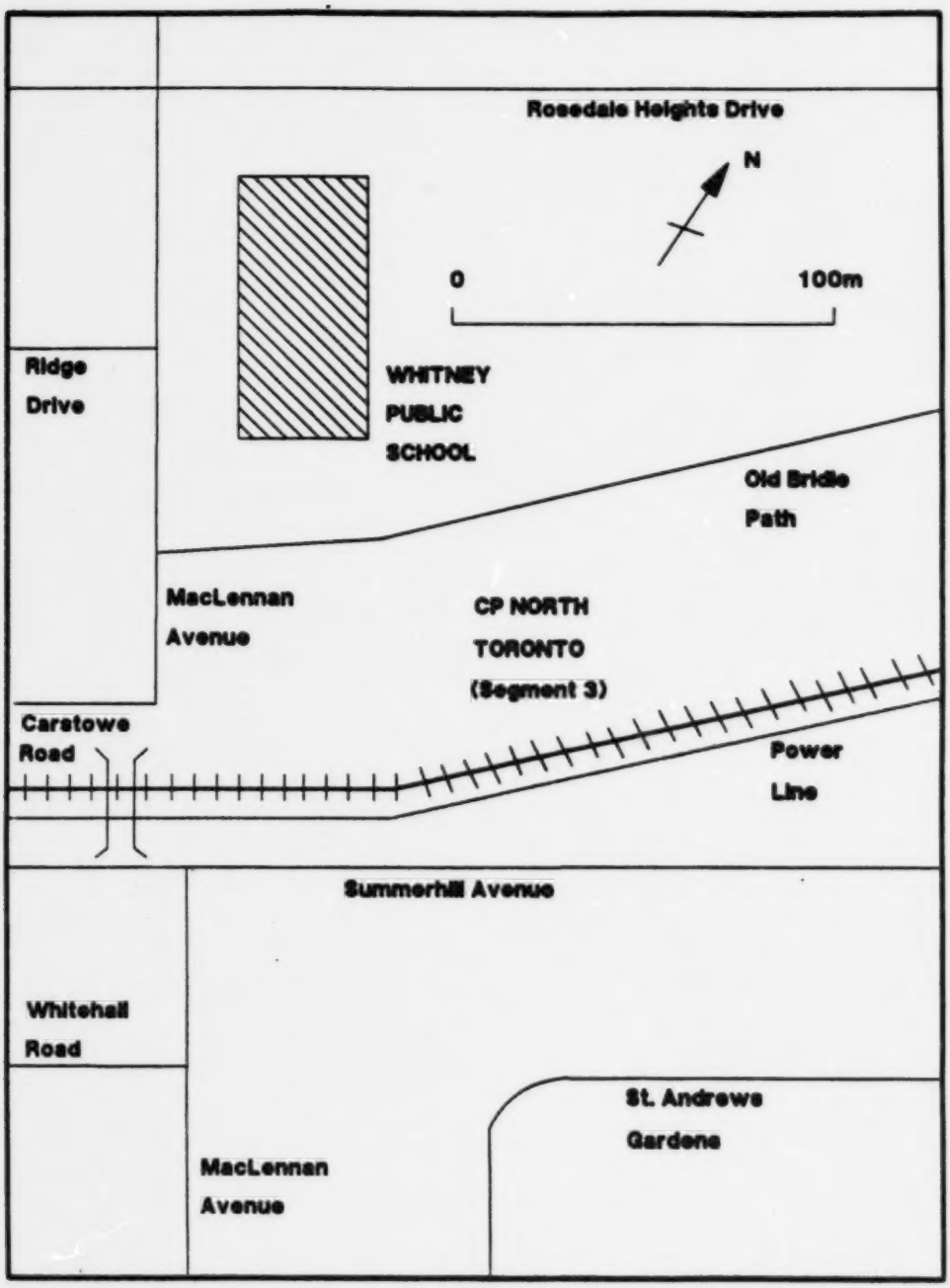
The Whitney Public School is at 119 Rosedale Height Drive (Figure 2.16). The school is located on a hill to the north of the main freight corridor (Segment 3). This location is an example of a school located in a residential area of the City. The number of students at the school is 421 and the number of staff is 20. Old Bridal Path is located to the south of the school. A row of houses is found on the south side of the rail line within a few meters of the rail property. The school is approximately 90 m from the rail line. Hydro power lines are located along the south side of the rail line. (A hazard analysis of this area has been performed by Klement and Napier (1986)). The elevation of the school (an estimated 14 m) offers considerable protection against physical impact of a derailed train or a chlorine release.

The most significant hazard to the school would be a fireball from a BLEVE following a propane accident. The effects would include: thermal radiation from a fireball, blast waves from the release and possible missiles from the explosion. The houses located south of the rail line are at immediate risk to the direct effects of a rail accident.

Of the foregoing public facilities of key concern, the following were selected, in cooperation with City officials, as being representative of (high density)

FIGURE 2.16

Whitney Public School



residential land-use facilities:

- The Ports;
- St. Rita's Catholic School;
- Christie Gardens Apartment and Care;
- George Brown College (Casa Loma Campus); and
- Whitney Public School.

3.0 RISK ASSESSMENT METHODOLOGY

The models and techniques used by Concord Scientific Corporation for risk analysis of dangerous goods carried by rail transport have been previously described in detail (Concord, 1987). A summary of the key features of the approach as applied in the present study, and depicted in Figure 3.1, will be presented in this section. The four basic components of the assessment are:

- identification of hazardous events;
- estimation of the consequences of hazardous events;
- estimation of the frequencies of hazardous events; and
- computation of risk for rail segments under consideration.

3.1 IDENTIFICATION OF HAZARDOUS EVENTS

This topic has been dealt with in detail in the previous study (Concord, 1987). It will be reviewed briefly in this section in order to present a coherent account of the risk methodology.

3.1.1 Selection of Representative Chemicals for Classes of Dangerous Goods

Surrogate materials have been selected as representative of those carried on the rail network in the City. The selection for each class/division of DGs is shown in Table 3.1 and the resultant list of materials considered in this report is:

- ammonia;
- chlorine;
- explosives (black powder);
- gasoline;
- oleum (30% free SO_3);
- phosphorus; and
- propane.

FIGURE 3.1
Risk Assessment Methodology (Simplified)

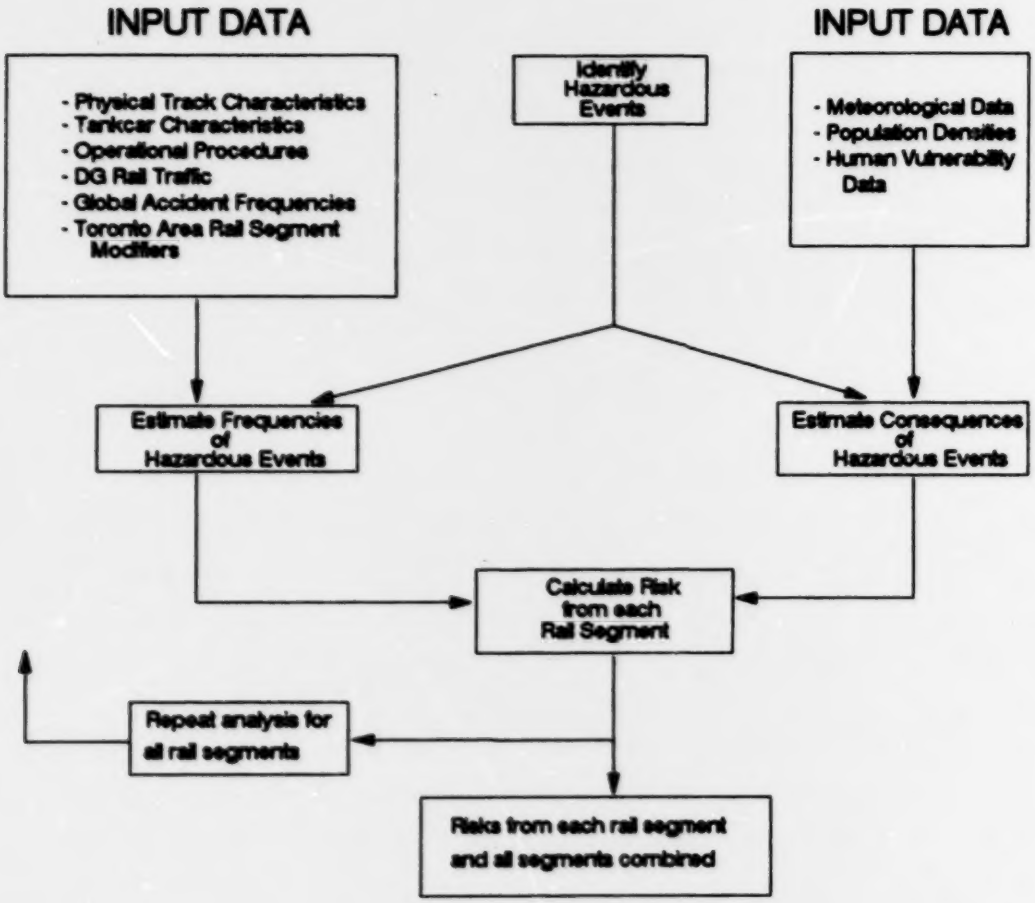

INPUT DATA
- Physical Track Characteristics
- Tankcar Characteristics
- Operational Procedures
- DG Rail Traffic
- Global Accident Frequencies
- Toronto Area Rail Segment Modifiers
Identify Hazardous Events
INPUT DATA
- Meteorological Data
- Population Densities
- Human Vulnerability Data
Estimate Frequencies of Hazardous Events
Estimate Consequences of Hazardous Events
Calculate Risk from each Rail Segment
Repeat analysis for all rail segments
Risks from each rail segment and all segments combined

TABLE 3.1

Selected Representative Chemicals

TDGR Class.Division	Class Description	Chemical Selected	Comments
1	Explosives	Black Powder	Model blast wave
2.1	Flammable Liquefied Gases	Propane	Model heavy gas/mist cloud dispersion, jetfire, fireball.
2.2	Liquefied Gases	-	Group with 2.1
2.3	Toxic Gases	-	Group with 2.4 as chlorine
2.4	Corrosive Gases	Chlorine and Ammonia	Cl_2 Traffic known, remainder of class 2.4 taken as NH_3. Model heavy gas/mist cloud dispersion
3.1	Flammable Liquids (F.P. <-18C)	Gasoline	Model pool fire, jet-fire
3.2	Flammable Liquids (-18 < F.P. <23C)	-	Group with 3.1
3.3	Flammable Liquids (F.P. >23C)	-	Group with 3.1
4.1	Flammable Solids	-	Group with 4.2
4.2	Spontaneously Flammable Solids	Phosphorus	Model P_4O_{10} cloud dispersion
4.3	Substances that on contact with water emit flammable gases	-	Group with 2.1
5	Oxidizing substances and organic peroxides	-	Group "Special Dangerous Commodity" Traffic (as H_2O_2) with 8.1; model H_2O_2 mist as SO_3
6.1	Poisonous substances	Oleum/SO_3	Model H_2SO_4 heavy mist cloud dispersion
6.2	Infectious substances	-	Group with 6.1
7	Radioactive materials	-	Special Case
8	Corrosive substances	-	Group with 6.1
9	Miscellaneous	-	Group with 6.1

Note: F.P. = Flash Point
TDGR = Transport of Dangerous Goods Regulations

Selection of a material was based on the following criteria:

- large volumes of the material are hauled by rail; and
- the material has the greatest potential for harm in its class.

It has been assumed that the total volume of materials hauled on a rail segment can be represented by one or more of the seven materials selected. This representation is in terms of full tankcars of the selected material accounting for the entire amount of the relevant category. A special note is required for the case of oleum. Oleum falls into three different classes according to the TDG regulations. These classes include classes 6.1 (poisonous), 8 (corrosives), and 9.1 (misc.). For this study, oleum was chosen as a surrogate for class 6.1 due to the large volume of oleum and the toxic effects of oleum. Also, all corrosive materials were represented by the surrogate for class 6.1.

3.1.2 Selection of Hazardous Events

Release of materials listed in Section 3.1.1 that results from loss of containment from rail cars, may cause one of several types of hazard that impinge on the population in the environs of the rail corridors. The hazards identified and selected for consideration in the present study are listed in Table 3.2 with the materials involved.

All of the hazards listed in this section have been incorporated into the estimation of risk to the public adjacent to the rail corridors. The case of derailment leading to physical impact was considered qualitatively for the situation in the main freight corridor and initial risk estimates were made along the passenger corridor.

3.2 FREQUENCY OF OCCURRENCE OF HAZARDOUS EVENTS

The same type of input data has been used in this study as previously (Concord, 1987):

TABLE 3.2

Selected Hazards and Materials Involved

Hazard	System	Material
Acute toxicity	Dispersion of toxic gases and vapours	chlorine, ammonia, phosphorus pentoxide
Flame impingement	Flash fires	propane
Thermal radiation	Fireballs	propane
	Jet fires	propane, gasoline
	Pool fires	gasoline
Blast	Confined explosions	residue propane and gasoline cars
	Detonations	explosives (black powder)
	BLEVE	propane

- DG rail traffic;
- physical track characteristics;
- tankcar characteristics;
- global accident frequencies;
- operational procedures;
- Toronto area rail segment modifiers; and
- meteorological data.

This collection of data has been brought together to estimate the frequency of specific events and hence the frequency of occurrence of the consequences at a given location. Thereby individual risk may be estimated.

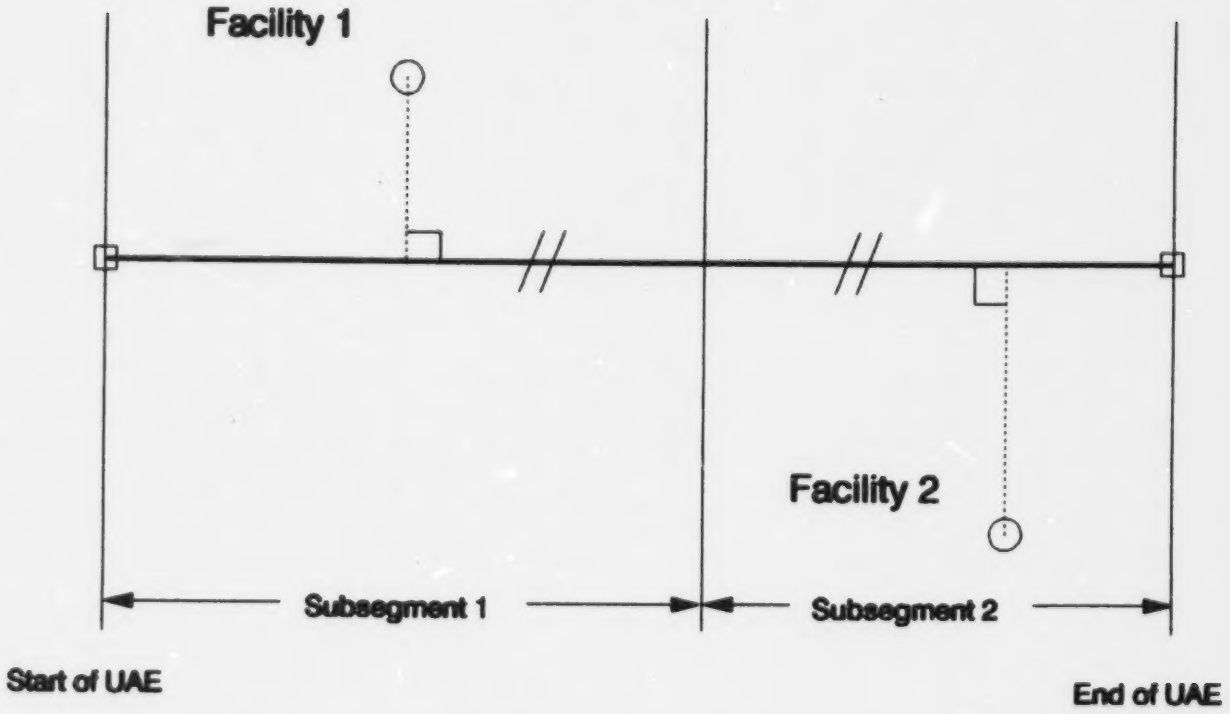
In order to estimate societal risk, it is necessary to incorporate population data. Two different sets of population data have been used in the present work. The format and averaging for daytime and nighttime populations are the same as used for the Greater Toronto Area study (Concord, 1987). The same population densities have been used for segments 4 to 13 as in the previous study. However, the emphasis of this study is on risk estimates along the main freight corridor and a more highly resolved grid (especially in the near-field) for population density was utilized in the risk estimates. Segments 1, 2 and 3 that comprise the main freight corridor were divided into subsegments based on the assumption of equal population density. The basis of this segmentation is as follows:

- Segments 1, 2 and 3 are Uniform Accident Environment (UAE)-based segments.

- The distribution of population densities around a fixed facility is assumed to be uniform across to the midpoint of the track segment as illustrated in Figure 3.2.

The detailed population densities were supplied by the Department of Planning and Development of the City of Toronto. The facilities used as a basis for

FIGURE 3.2
Basis for Subsegmentation
of Main Freight Corridor



population density are summarized below in Table 3.3. These facilities were used to subdivide Corridor I, the main freight corridor, into subsegments of equal population. The subsegments are shown in Figure 3.3.

The population data do not include transients (e.g. visitors or commuters) in the area. The source for the residential population data was the 1988 Provincial Assessment File. The source for the employment data was the Metropolitan Toronto Planning Department, E.L.A., 1988. Projection in population changes were not made due to the high degree of error associated with the method of analysis for limited distance from the railway corridor. This is also complicated by the uncertainty of future policy decisions re land-use restrictions.

Therefore, the risk analysis is based on a single year's population figures and it must be recognized that any increases or decreases in population densities would increase or decrease, respectively, societal risk estimates.

3.3 CONSEQUENCES OF HAZARDOUS EVENTS

For the hazards listed in Section 3.1, computer models have been used to determine the variation of the consequences with distance from the site of the incident. The degree of human vulnerability has been combined with these estimates of concentration of toxic gas/vapour, thermal radiation or overpressure as may be appropriate to the hazard. Thereby a realistic estimate has been obtained of the individual risk at a point and the societal risk, in terms of fatalities, due to a given hazard.

3.4 COMPUTATION OF RISK

In its essentials, risk is determined from the product of frequency of occurrence and consequences. The units used in this study are:

TABLE 3.3

Facility Locations Used for Population Density Data

Rail Subsegment	Location
1	National Rubber - Cawthra
2.1	National Rubber - Symington
2.2	BASF Inmont Canada Inc.
3.1	Christie Gardens
3.2	TTC Hillcrest
3.3	George Brown College
3.4	The Ports
3.5	Whitney Road Public School

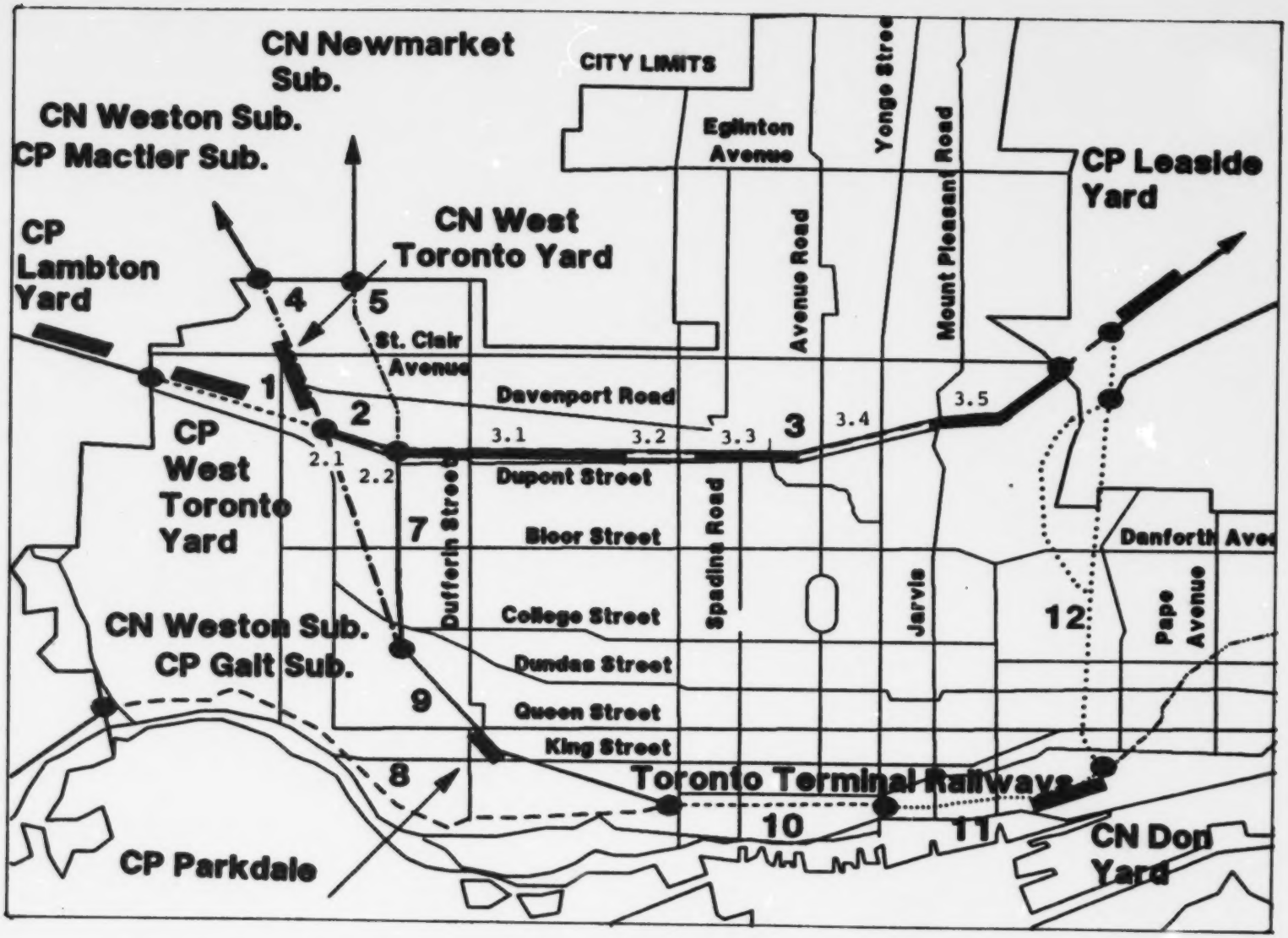


FIGURE 3.3

Rail Subsegments Used for the Main Freight Corridor

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- **individual risk:** chances per year of death for an individual at a specified location from the potential effects of rail traffic on a given segment of track; and

- **societal risk:** the statistical number of fatalities per year among the exposed population from the potential consequences of accidents on a segment of track.

In the estimation of risk, account is taken of the factors listed in Section 3.2 as input data. Thereby, the historical characteristics of accident frequency on the specified segment of track, are incorporated into the computation of risk.

Risk to the public has been estimated for each of the rail segments in the City identified in Table 3.3 as well as for all segments combined. Analyses have been performed to estimate the reductions in risk possible through the implementation of alternative buffer zones or set-back distances.

4.0 DISCUSSION OF RISK ESTIMATES

The results of the risk assessment are presented in this section. To provide some perspective on the estimated levels of risk, and to assist in the evaluation of the acceptability of these risks, some relevant information on common risks, risk criteria and acceptability of risk is also given.

4.1 RISK CRITERIA AND ACCEPTABILITY OF RISK

Decisions with respect to the acceptability of risk are personal and social value judgements, involving the public exposed to the risks, government agencies and the industrial proponent of the risk-bearing project or system (i.e., the rail network).

Guidelines or criteria on the acceptability of public risk from hazardous facilities do not exist in Canada. Some guidance on the acceptability of risk of death is offered by the following sources. Knox (1975), who carried out a careful study over a wide range of statistics, put the acceptable level on individual risk at one in 100,000 (or 10 in a million). The Royal Society Study Group (1983), and the Health and Safety Executive (HSE) (1988) suggested the following criteria for acceptability of risks:

- one in 1,000 (1,000 in a million) per year for the intolerable level of individual risk even when the person exposed "judged he had some commensurate benefit" (e.g., as in risk at work or leisure);

- one in 10,000 (100 in a million) per year as the intolerable level for any individual member of the public (this level being 10 times lower than the intolerable level for workers at risk or the sports risk taker, it is comparable to the annual average risk of dying in a traffic accident in the U.K.); and

- one in 1,000,000 as the level below which risks could "legitimately be regarded as trivial".

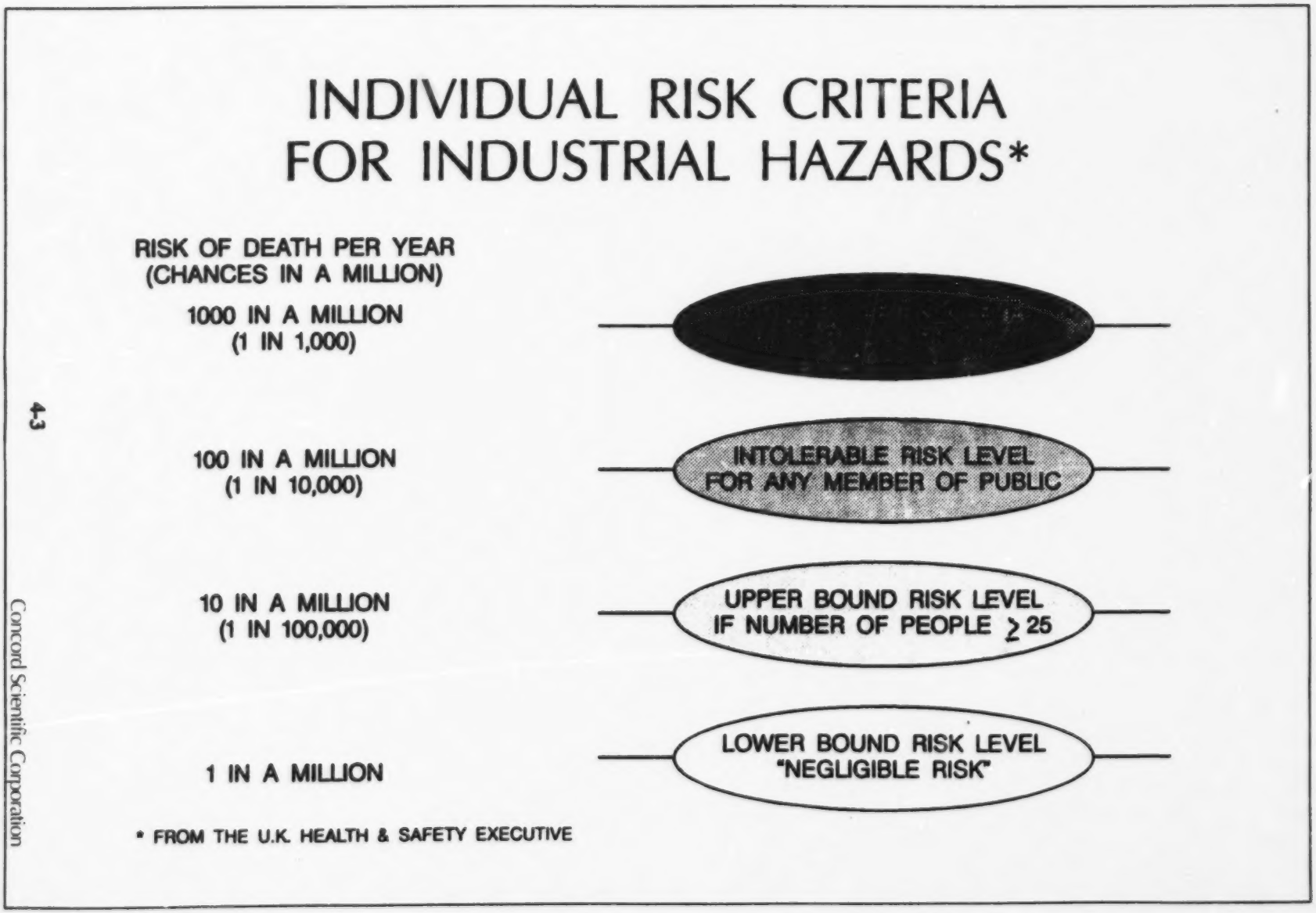
The Netherlands has adopted probably the most stringent criteria on acceptability of risk, where individual risk levels above one in a million are considered unacceptable and at levels between one in a million and one in 100 million, considered possibly justifiable, and below one in 100 million trivial or clearly acceptable (Versteeg, 1988). These criteria are significantly at variance with other published risk guidelines or criteria and are presented here only as a point of reference.

Recently, the HSE (1989) adopted the following risk criteria for land-use planning in the vicinity of major industrial hazards: an upper bound of 10 in a million per year, where the number of exposed persons exceeds 25 and a lower bound of one in a million per year, below which risks are considered negligible. This upper bound is 10 times lower than the intolerable level for any individual member of the public, referred to earlier, or the risk of being killed in a traffic accident, and the lower bound is about 10 times as great as the risk of being killed by lightning in the U.K. Between these two bounds, judgement is applied taking into consideration the number of people exposed and the cost-benefits of risk reduction.

The foregoing criteria from the U.K. have been cited because some of the earliest work on quantitative risk assessment was undertaken in the U.K., and the HSE has extensive experience in the area of risk assessment and risk criteria having been involved in about 5,000 developments requiring detailed assessments in the past 15 years. However, the HSE document explicitly states that the risks associated with transportation systems were not considered for their criteria document. Nevertheless, the published values serve as a basis of comparison and provide some guidance on the acceptability of risk. Figure 4.1 provides a summary of these criteria.

FIGURE 4.1

HSE Risk Criteria


INDIVIDUAL RISK CRITERIA
FOR INDUSTRIAL HAZARDS*
RISK OF DEATH PER YEAR
(CHANCES IN A MILLION)
1000 IN A MILLION
(1 IN 1,000)
100 IN A MILLION
(1 IN 10,000)
INTOLERABLE RISK LEVEL
FOR ANY MEMBER OF PUBLIC
10 IN A MILLION
(1 IN 100,000)
UPPER BOUND RISK LEVEL
IF NUMBER OF PEOPLE ≥ 25
1 IN A MILLION
LOWER BOUND RISK LEVEL
"NEGLIGIBLE RISK"
* FROM THE U.K. HEALTH & SAFETY EXECUTIVE

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In considering the HSE criteria in the context of the current study, it is important to recognize that the application of results from risk assessments is a developing field of endeavour, and no universally accepted guidelines exist. As discussed later in this section, estimated risk values should be considered in this context.

In discussing levels of risk, it is also useful to compare the values computed with those encountered in other activities. Such comparisons are frequently used in the evaluation of acceptability of risk. For this purpose, Table 4.1 has been prepared to provide levels of some common risks which people experience in everyday life in Canada and Metropolitan Toronto. These data are based on actual fatality statistics compiled by the federal and provincial government departments identified in the notes of the table. As a further aid in interpreting risk numbers, Table 4.2 contains a list of small numbers in relation to common measures.

In the evaluation of the acceptability of public risks from a hazardous facility, other factors in addition to the risk should be carefully weighed. These other factors can be broadly grouped into: 1) economic considerations (e.g., need for and benefits from the facility, costs of risk reduction); and 2) socio-political considerations (e.g., impacts on both the community and natural environment impacts and public perceptions).

4.2 INDIVIDUAL RISK

The estimated levels of individual risk due to dangerous goods rail transport along the various rail corridors in the City will be presented in this section.

An effective method of displaying estimates of individual risk at a specific location, and especially in the consideration of appropriate set-back distances, is to plot the variation of levels of individual risk against distance from the track. Such profiles of individual risk are shown in Figures 4.2 to 4.5 for the 13 rail segments analyzed (refer to Figure 2.1).

TABLE 4.1

Some Common Risks in Canada and Metropolitan Toronto

Cause or Hazard	Individual Risk (chances in a million of death per year)	
	Canada[1]	Metropolitan Toronto[2]
Motor Vehicle Accident	159	75[3]
Falls	75	102
Fires	20	12[4]
Poisoning	15	28
Excessive Cold	4.4	N/A
Cataclysmic Storms	0.3	0
Lightning	0.2	0

Notes:

1. Data are for a three year period (1984-86).

2. Data are for a two year period (1985-85) from Registrar General, Province of Ontario publication "Causes of Death for Metropolitan Toronto. Note that basis of inclusion of fatality in database was residing in Metropolitan Toronto.

3. This figure represents the individual risk of death by motor vehicle accidents for Metro Toronto residents only and would be higher if non-resident drivers killed in motor vehicle accidents were included.

4. Data for 1988 from the Office of the Fire Marshall.

5. Population figures from Ministry of Supply and Services (1987).

6. N/A = not available.

TABLE 4.2

Small Numbers in Relation to Common Measures

EQUIVALENT NUMBERS	APPROXIMATE RELATIONSHIPS
10 percent 1/10 0.1 10^{-1}	2 hours per day 1 year per decade (exact)
1 percent 1/100 0.01 10^{-2}	2 hours per week 1 year per century (exact) one year per lifetime
0.1 percent one in a thousand 0.001 10^{-3}	1 minute per day 1/2 day per year 1 month in a lifetime
0.01 percent one in ten thousand 0.0001 10^{-4}	1 hour per year 1 drop in a litre (quart) of water 1 long weekend in a lifetime (3 days)
1/100,000 one in a 100,000 0.00001 10^{-5}	1 night's sleep in a lifetime 1 drop in a bucket of water 10 minutes per year
1/1,000,000 one in a million 10^{-6} 1 ppm	30 seconds per year 1 family in the population of Alberta 1 eyedropper of water out of a bathtub full
1/10,000,000 one in ten million 10^{-7}	3 seconds per year 1 drop in a bathtub 1 family in the population of Canada
1/100,000,000 1 in a hundred million 10^{-8}	1 eyeblink in a year 1/2 minutes in a century 20 seconds in a lifetime
one in a billion 10^{-9} 1 ppb	5 years out of the life of the earth 2 seconds in a lifetime 1 family out of the earth's population

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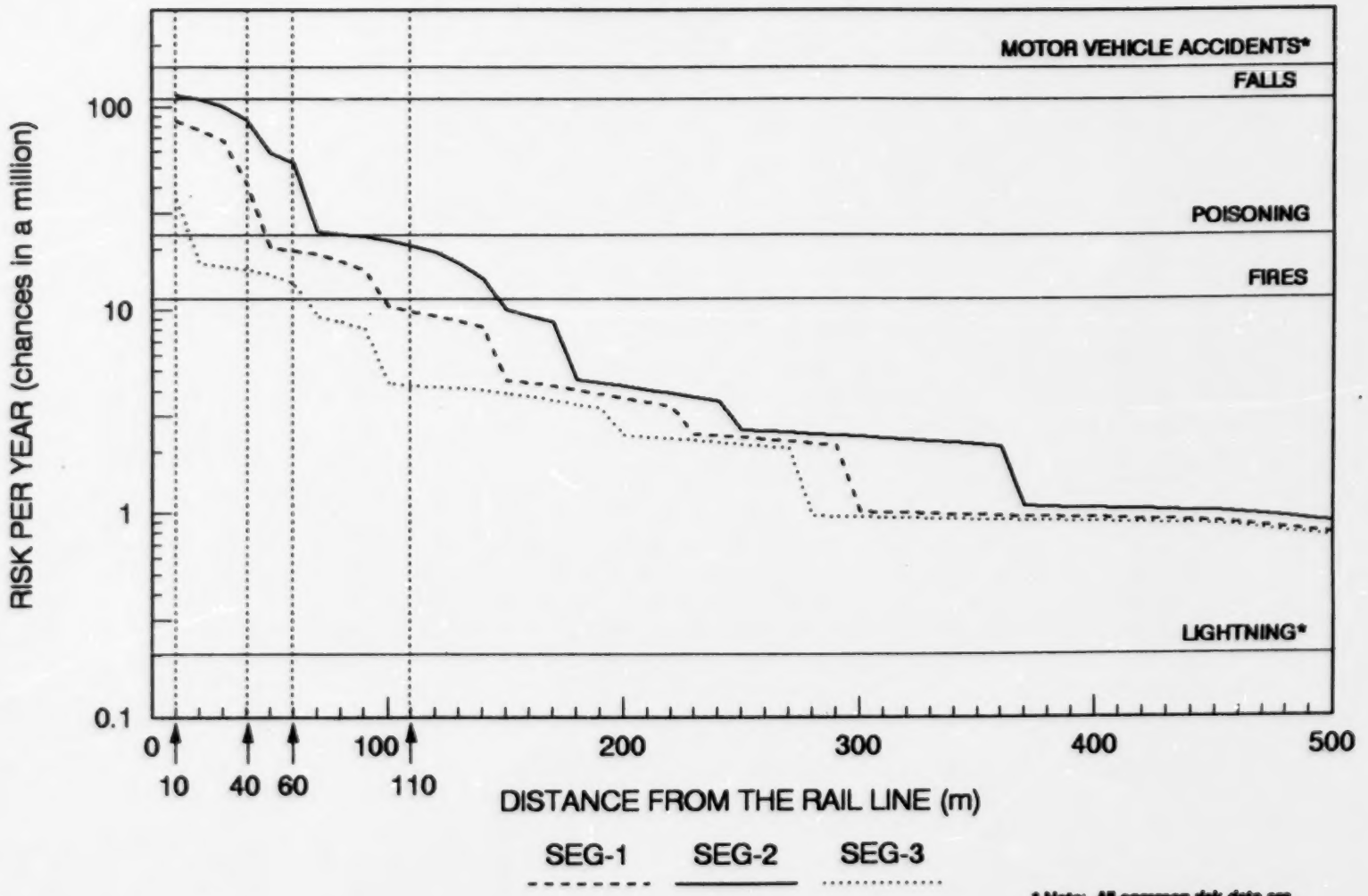
FIGURE 4.2

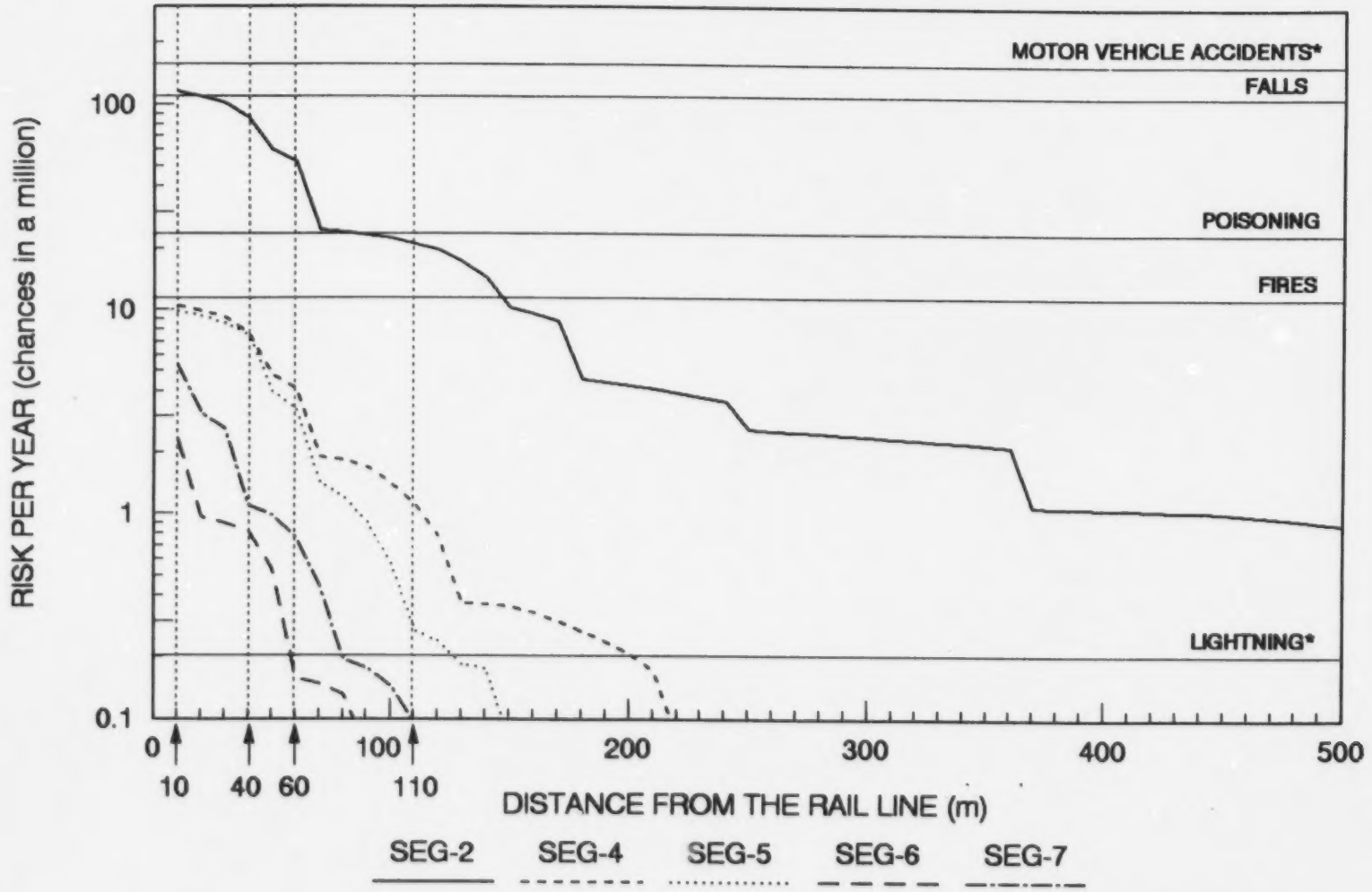
INDIVIDUAL RISK PROFILES FOR RAIL SEGMENTS



* Note: All common risk data are for Metro Toronto except those noted by "*" which are Canada-wide data.

FIGURE 4.3

INDIVIDUAL RISK PROFILES FOR RAIL SEGMENTS



* Note: All common risk data are for Metro Toronto except those noted by "*" which are Canada-wide data.

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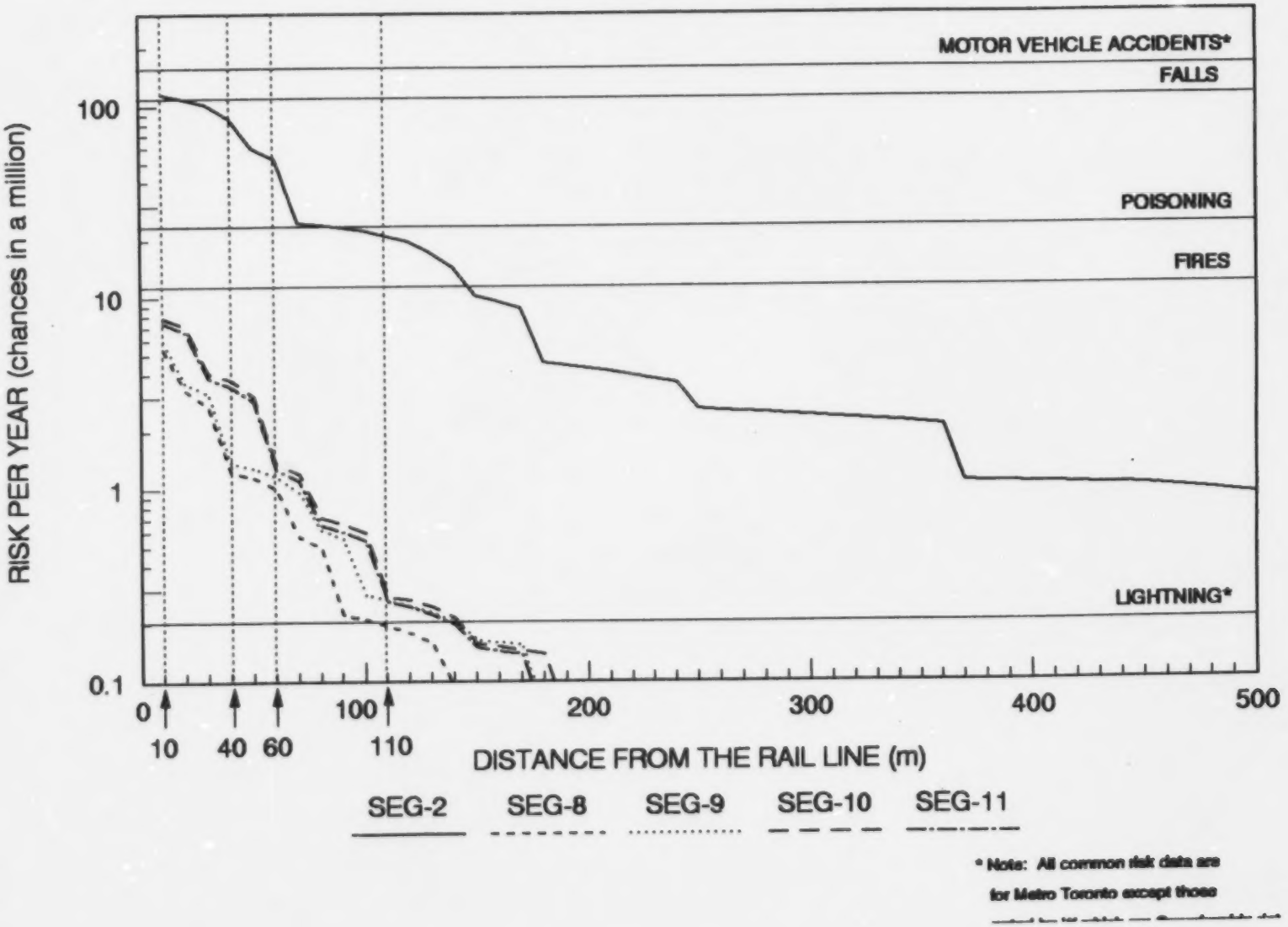
FIGURE 4.4

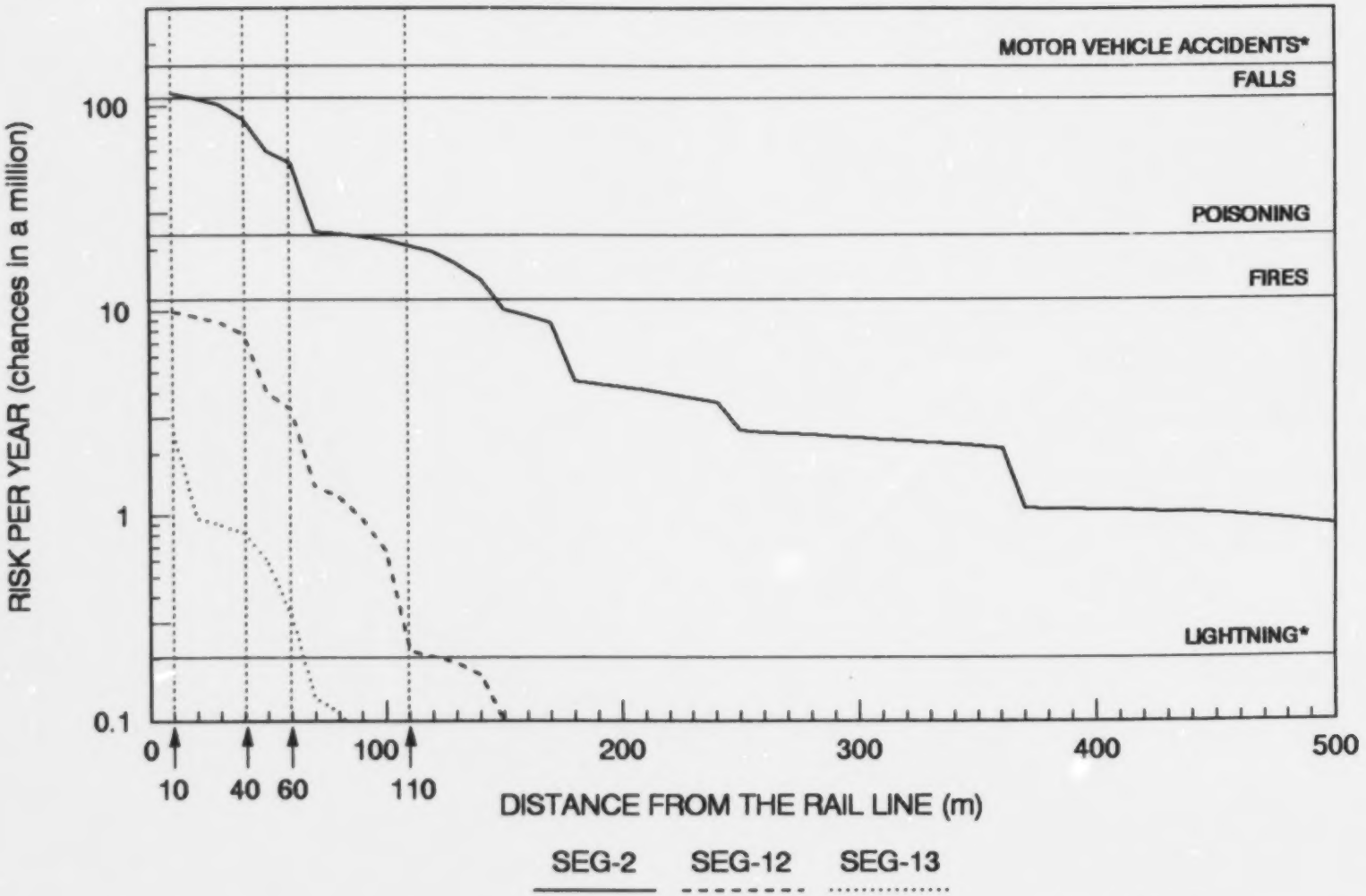
INDIVIDUAL RISK PROFILES FOR RAIL SEGMENTS



* Note: All common risk data are for Metro Toronto except those

FIGURE 4.5

INDIVIDUAL RISK PROFILES FOR RAIL SEGMENTS



* Note: All common risk data are for Metro Toronto except those

Concord Scientific Corporation

In Figure 4.2, profiles of individual risk are given for rail segments 1, 2 and 3, which comprise the main freight corridor. The zero ("0") location on the horizontal axis of Figures 4.2 to 4.5 represents the location of the rail line. As one would expect, risk decreases with increasing distance from the rail line. The significance of the magnitude of a risk may be better appreciated by comparing it with the level of risk associated with more common and familiar events. To facilitate such comparison, values for the levels of individual risk of some of the events listed in Table 4.1, have been marked on Figures 4.2 to 4.5.

The vertical dashed lines at 10, 40, 60 and 110 m on Figures 4.2 to 4.5 should be noted. A distance of 10 m from the rail line corresponds roughly to the edge of the railway right-of-way (generally 66 feet in total width). The other distances correspond to set-backs (measured from the edge of the right-of-way) of 30, 50 and 100 m, which have been selected for specific analyses to be presented in Sections 4.4 and 5.2.

It will be noted that the highest level of individual risk is associated with segment 2, where the maximum risk is just over 100 chances in a million per year at about 25 m from the rail line. This level corresponds to the individual risk of death per year from falls in Canada. At about 75 m from the track, the level of risk is approximately the same as that for poisoning in Metropolitan Toronto. The level of risk drops to 10 in a million at about 150 m (comparable to that for fires in Metro Toronto) and to 1 in a million at about 450 m from the rail line.

An examination of Figures 4.2 to 4.5 indicates that all of the segments have lower risk levels associated with them than segment 2.

The different levels of risk amongst the rail segments can be generally attributed to the following variations between them:

- different types and volumes of DG traffic;

- different frequencies of potential DG releases, depending on accident frequencies and track characteristics;

- differing length of track (each risk profile is based on the estimated levels of risk to an individual from the specified segment only); and

- differing orientations with respect to predominant wind directions.

When evaluating these risk estimates, it is important to note the uncertainties in the estimates. As discussed previously (Concord, 1987), in general, these uncertainties in the risk analysis are of three types:

- Bias introduced in the selection of, for example, the representative chemicals or for the type of release events. The bias introduced here is on the conservative side (i.e., it will lead to higher estimates of risk than those extant).

- Uncertainties due to errors in input data, such as accident frequencies, population data, meteorological data, etc. These errors would normally be random and not introduce any systematic bias in the risk estimates.

- Uncertainties due to model simplifications and assumptions in the consequence models or in the rail system model used in estimating event frequencies. The assumptions in these models are in general made so that the results from the model would "err on the safe side", i.e., lead to higher estimates of risk than those extant.

The overall impact of these uncertainties is expected to produce conservative estimates of risk. The actual risks are likely to lie between an upper limit of two times and a lower limit of one-tenth of the estimates given. These uncertainties are of particular importance when evaluating the absolute values of the estimated

risks. When relative risks are being considered, as in comparison of risk levels between various rail segments, there is much greater confidence than the above uncertainties might indicate. This is due to the fact that the risk estimates for each rail segment have uncertainties to the same direction (e.g., risk estimates would be high by about the same magnitude).

Thus, when considering the risk profiles of Figures 4.2 to 4.5, each profile is subject to the uncertainty bars noted above. Thereby, each profile should be regarded as being within a band or range.

Another observation on the risk profiles is that segments 6 and 13 present the lowest levels of risk. This is noteworthy as it illustrates an important result from the analysis. The release of special dangerous commodities such as chlorine from a tank car and its subsequent dispersion produces the possibility of lethal consequences at large distances from the track. Thus, those segments over which such commodities are hauled produce higher levels of individual risk that extend to greater distances from the track. Segments 6 and 13 haul the lowest volumes of SDCs; the risks along these segments are due in the main to potential fires and explosions. The local (i.e., near-field) consequences of such incidents can be severe but they are limited in extent compared with those for commodities such as chlorine. The most far-reaching effect of LPG is due to flash fires; the frequency of large flash fires in a densely populated area is low because of the multiplicity of sources of ignition. The extent of the dispersion is thereby limited.

Table 4.3 presents the estimated maximum levels of individual risk at distances of 10, 40, 60 and 110 m from the rail line. These results can be categorized as follows:

1) Only segment 2 has a risk value of greater than 100 chances in a million per year.

2) Only segments 1, 2, 3 and 4 have risk values greater than 10 chances in a million per year.

TABLE 4.3

Estimated Maximum Levels of Individual Risk at 10, 40, 60 and 110 m From Rail Lines

Rail Segment	Maximum Individual Risk (chances in a million of death per year)			
	10 m*	40 m	60 m	110 m
1	85	43	20	10
2	115	86	53	21
3	35	16	14	4.3
4	11	7.6	4.1	1.1
5	9.9	7.5	3.3	0.3
6	2.3	0.8	0.2	0.03
7	5.3	1.1	0.8	0.1
8	5.4	1.2	1.0	0.2
9	6.0	1.4	1.2	0.3
10	7.9	3.8	1.4	0.3
11	7.5	3.4	1.3	0.3
12	9.9	7.6	3.3	0.2
13	2.5	0.8	0.3	0.02

* 10 m is roughly the distance to the edge of the railway right-of-way.

3) Segments 5 through 13 have risk values less than 10 but greater than 1 chance in a million per year.

These individual risk results will be discussed further in Section 4.4 which examines set-backs and risk reduction potential.

4.3 SOCIETAL RISK

While it is important to examine the risks to individuals, the risk to societal groups or the public-at-large must also be considered. Societal risk is a function of (or determined by) the total exposed population in an area (population density) whereas individual risk is a function of an individual's behaviour pattern (e.g., location of residence, time spent at residence, etc.). It is possible to have situations in which there is high individual risk but low societal risk, because the number of exposed persons is small, and conversely, it is possible to have high societal risk with low individual risk.

To illustrate this point with some extreme examples, the following may be considered. If there was only one person living close to a hazardous chemicals plant, the risk to this individual could be relatively high, but the societal risk would be low. On the other hand, if a shopping mall were the only building close to the plant, then the risk to individual shoppers could be very low since people spend only a small percentage of time shopping, whereas there may be a large number of exposed people at the mall at any one time, which could create a high societal risk. It is important to consider both individual and societal risks when evaluating the acceptability of risk from hazardous facilities.

Societal risk has been estimated for each of the rail segments in the City in terms of fatalities per year, as given in Table 4.4. As the primary focus of this study is on the main freight corridor (segments 1, 2 and 3), segments 2 and 3 were subdivided to enhance the resolution of the risk analysis through the use of the

detailed population data available for each of the sub-segments from the City's Planning and Development Department.

The overall societal risk due to DG rail transport operations within the City is obtained by summing the societal risk due to all rail segments. This result was calculated to be 0.32 statistical fatalities per year (or 1 fatality per 3.1 years), as shown in Table 4.4. The societal risk for the entire Greater Toronto Area (GTA) was estimated by Concord (1987) to be about four statistical fatalities per year, wherein the societal risk for the City area was approximately 0.6 fatalities per year. The risk study for the GTA included about 754 km of rail lines carrying DGs through five municipalities, whereas in the current study for the City, only about 41 km of rail lines are involved. Also, this study employs 1988 data for CP DG rail traffic, which is significantly different from the 1985 data used in the 1987 risk study. The reduction of about 46% in the estimated overall societal risk, from 0.6 to 0.32 fatalities per year for the City, is due to the change in CP's DG traffic volumes from 1985 to 1988 (about 60% of the reduction) and due to the more highly resolved population data (about 40% of the reduction) that were used in the present study.

As the main freight corridor is the main interest in this investigation, it should be noted from Table 4.4 that the estimated total societal risk from segments 1, 2 and 3 (0.1331 fat/yr.) is about 41% of the network total (0.322 fat/yr.). This means that on the basis of this risk analysis the main freight corridor contributes 41% of the total DG rail transport risk to the public in the City of Toronto.

TABLE 4.4

Societal Risk Estimates for City Rail Segments

Segment No.	Length (km)	Societal Risk Rate (fat/km.y)	Societal Risk (fat/y)
1	1.82	.00959	.01745
2.1	0.68	.03419	.02325
2.2	0.20	.01429	.00280
3.1	2.39	.02708	.06472
3.2	0.63	.00357	.00225
3.3	1.04	.00646	.00672
3.4	1.48	.00182	.00270
3.5	1.32	.00999	.01318
4	1.66	.01562	.02593
5	1.82	.00986	.01794
6	2.60	.00272	.00707
7	2.27	.00361	.00819
8	6.20	.00720	.04463
9	3.39	.00880	.02982
10	2.05	.01171	.02401
11	2.32	.00117	.00272
12	3.13	.00853	.02671
13	5.93	.00037	.00221
Network Total:		.00787	.322

Some further discussion on the societal risk estimate of 0.32 fatalities per year for the City is required to put it into perspective. This risk estimate can be compared to some societal risks commonly experienced by the public in the City as given in Table 4.5 (which is derived from the same base data as Table 4.1 on individual risks for Metro Toronto and extrapolated to the City's population). The societal risk from DG rail transport in the City is about 22 times less than that due to fires and more than two orders of magnitude (a factor of 100) less than the risk due to falls and motor vehicle accidents.

One must make a distinction between the DG rail transport risks as estimated in this study and the other risks in Table 4.4. The rail risk estimates are in terms of what is usually termed as "statistical fatalities"; they are not the actual expected number of fatalities in any given year[1]. The average annual risk given in "statistical fatalities per year" reflects the likelihood that there might not be any such deaths over an extended period of years but there is always the possibility of an accident which could cause multiple deaths, thereby bringing the average up to the societal risk number given above (e.g., an accident which occurs once in 100 years in which there are 50 fatalities is equivalent to 0.5 fatalities per year, on average).

Having discussed the overall societal risk, the societal risks for the various rail segments given in Table 4.3 can now be examined. The best way to compare the societal risks amongst the segments is to divide the societal risk levels estimated for the segments by the respective lengths of the segments, which gives a societal risk rate in fatalities per year per kilometre of track, as shown in the table. (This permits an "apples to apples" comparison.) For ease of comparison, these values have been plotted in Figure 4.6 which depicts the distribution of societal risk within the City's rail network.

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1 *This is important to note since there have been no recorded deaths to date due to DG rail transport accidents in Canada. There have been deaths, however, from accidents involving trains which have collided with pedestrians, vehicles and other trains.*

TABLE 4.5

Societal Risks in the City of Toronto[1]

Hazard/Event	Societal Risk[2]	
	Fatalities Per Year	Frequencies of Fatalities (1 per ...)[3]
Motor Vehicle Accident[4]	46/97	8.0/3.8 days
Falls	62	5.9 days
Poisoning	17	21 days
Fires	7	50 days
City of Toronto DG Rail Transport Accident	0.32	1,134 days

Notes:

1 Sources of data as per Table 4.1, except population data for City of Toronto which was obtained from the City's Planning Department and DG Rail Transport Accident risk which was estimated in the present risk study.

2 These risk data have been extrapolated to the City from the Metropolitan Toronto data of Table 4.1.

3 Societal risk is expressed here as the frequency or interval between fatalities (e.g., on average, one fatality occurs per 50 days in the City due to fires)

4 Two values are given here. The first is the actual number of fatalities recorded in Metro extrapolated to the City and the second is the actual Canada-wide statistic extrapolated to the City. This has been done since the Metro Toronto statistics include only those who resided in Metro and were killed as a result of motor vehicle accidents and not the total number of fatalities which would obviously be greater.

FIGURE 4.6

Comparison of Societal Risk Rate Along Rail Segments

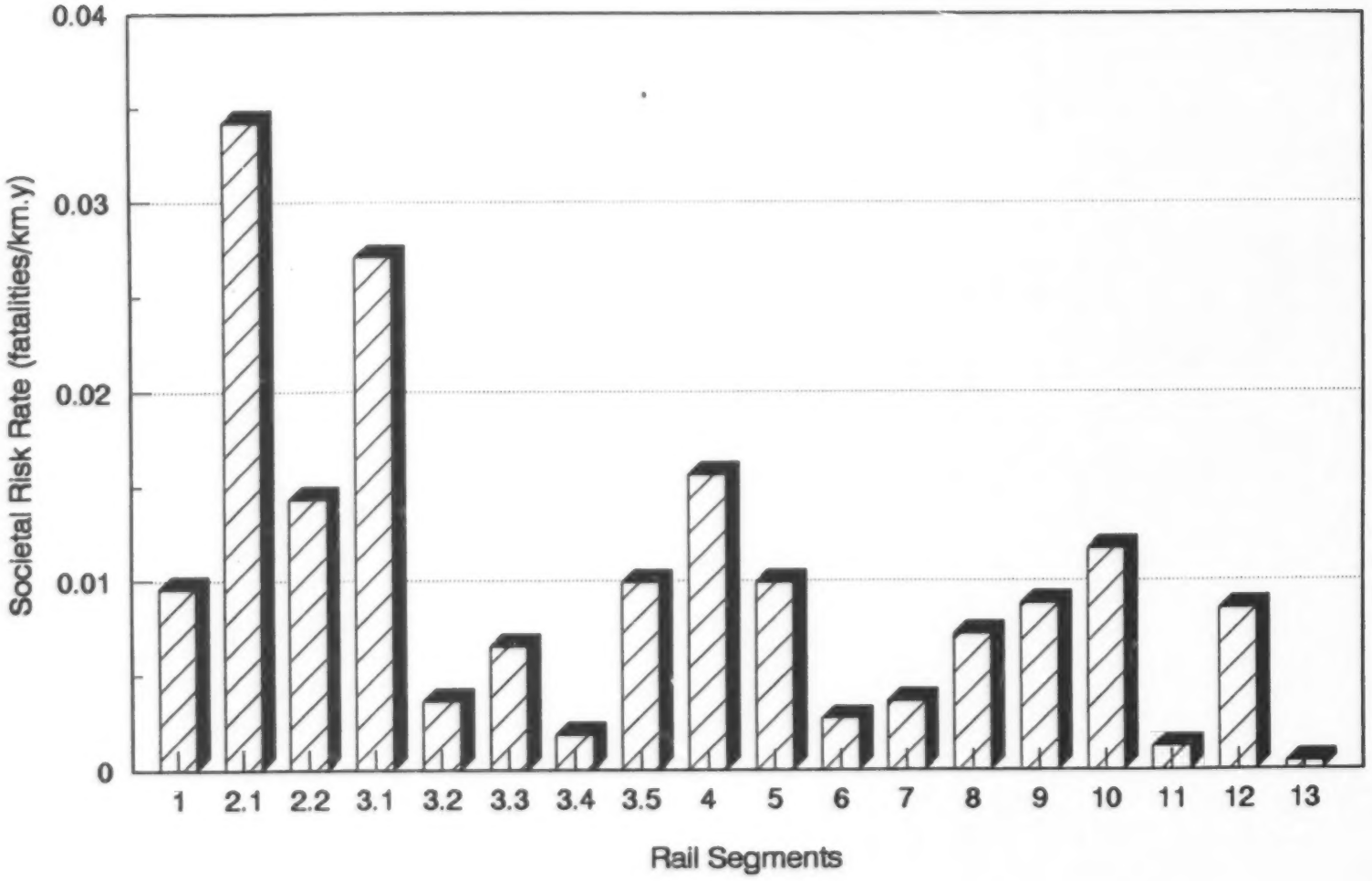


Figure 4.6 indicates that segments 2.1 and 3.1 have the highest societal risk rates (and therefore present the greatest risk to the public). These rates are significantly higher than the rates for most of the other segments. Segment 2.1 has the highest societal risk rate (.0314 fat/km.yr or 1 fatality per 29 years) which is about 92 times higher than the lowest societal risk rate of segment 13 (.00037 fat/km.yr or 1 fatality per 2,686 years). This means that the level of risk borne by people living in the vicinity of the highest risk segment is 92 times that borne by people living in the vicinity of the lowest risk segment.

The prime value of the information of Figure 4.5, for the purposes of the City's deliberations, is that it provides a key indicator as to where efforts and resources should be placed when considering set-backs or other risk mitigation measures.

4.4 SET-BACKS AND RISK REDUCTION

The concept of set-back as a form of risk mitigation is to prevent the use and therefore occupation of land adjacent to a source of risk (i.e., rail corridor). This idea is a common one in the chemical processing industries where a clear zone is created around a chemical plant, called the '*cordon sanitaire*'. Residences are not sanctioned in those zones, but a limited amount of light industry may be approved. This section examines the potential for reduction in public risk through the use of alternative set-back distances.

Given that railway right-of-ways generally are approximatly 10 m wide on either side of the rail line, set-backs are taken in this report to be measured from the edge of the right-of-way. A 30 m set-back, for example, means that the total distance from the rail line is 40 m (30 m set-back plus 10 m right-of-way). This convention is consistent with the practice of the City's Planning and Development Department.

Considering first the matter of individual risk, the information provided in Figures 4.2 to 4.5 can be reduced to a single table presenting the set-back distances required to reduce or maintain individual risk to various levels along rail segments. This has been done for the levels of individual risk, 100, 10 and 1 chances in a million of death per year, as shown in Table 4.6. The range of individual risk of 1 to 100 in a million is considered appropriate to examine here since risks below 1 in a million are generally considered insignificant and risks above 100 in a million (on the order of individual risk due to motor vehicle accidents) are generally thought to be quite high.

The following observations can be made from Table 4.6:

- If the acceptability limit on individual risk were taken to be 100 chances in a million per year, then a zero metre set-back affords acceptable levels of individual risk along all segments, except the segment 2 where a 31 m set-back would be required.

- If the acceptability limit on individual risk were taken to be 10 chances in a million per year, then a zero metre set-back affords acceptable levels of individual risk along all segments except segments 1, 2, 3 and 4 where set-backs of 3 to 142 m would be required.

- If the acceptability limit on individual risk were taken to be 1 chance in a million per year, then the set-back distances required to reduce estimated risk to this level along all rail segments range from 7 m for segments 13 to 450 m for segment 2.

TABLE 4.6

Set-back[1] Distances (m) Required to Reduce Individual Risk to Levels Specified

Rail Segment	Individual Risk (chances in a million of death per year)		
	100	10	1
1	*	98	324
2	31	142	450
3	*	59	270
4	*	3	103
5	*	*	77
6	*	*	10
7	*	*	39
8	*	*	50
9	*	*	58
10	*	*	70
11	*	*	65
12	*	*	76
13	*	*	7

* The maximum individual risk at 10 m from rail line is less than the level specified here.

1 These are set-back distances beyond the edge of the railway right-of-way. To determine total distance from the rail line add 10 m to the values.

The original intent for the present study was an examination of set-backs on the basis of only individual risk. In the interest of providing a more complete examination of the risk reduction aspects of set-backs, a limited set of analyses were performed on potential reductions to societal risk levels. These are discussed below.

Firstly, an analysis was performed on the societal risk reduction possible for a single hazard which has its greatest impact in the near-field. The hazard chosen was a fireball from a propane release. An exposed population of uniform density was considered for this specific analysis along segment 1 of the main freight corridor. The results are given in Figure 4.7 wherein the relative societal risks with alternate set-backs are plotted.

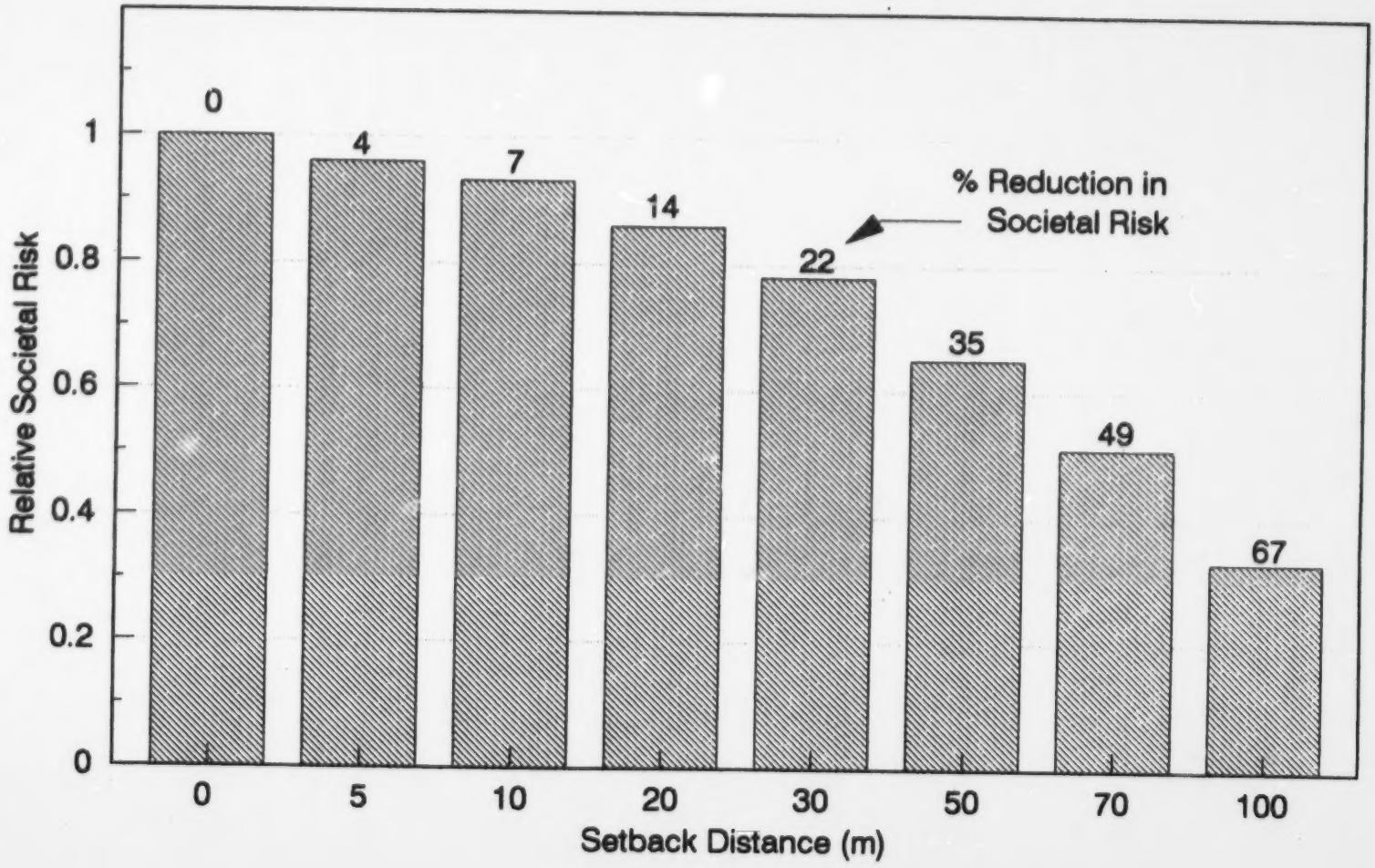
The first bar at 0 m set-back distance represents the maximum societal risk from this single hazard (if people lived right up against the rail line) and all other bars represent the estimated societal risks with different set-back distances relative to this maximum risk level. The percentage reduction in societal risk associated with each set-back is also noted.

To consider the potential reduction in risk for an area with an existing set-back, the difference in the percentages provides the necessary information. For example, if a set-back of 30 m currently exists, then the potential reductions in societal risk with a 50 and 100 m set-back are 13% and 55%, respectively.

This analysis indicates that substantial reductions in societal risk are possible for this hazard. This finding can be extended to other hazards that present risk to the public in the near-field only (e.g., fires and explosions). These findings do not apply to hazards that present risks to the public in the far-field (e.g., release of chlorine).

FIGURE 4.7

Relative Societal Risk with Differing Setback Distances for a Propane Fireball



A second analysis was performed along the lines of that described above for the complete set of hazards. This analyses was also somewhat idealized and assumed a uniformly distributed population for the exposed area along segment 1 of the main freight corridor. The results of this analysis are depicted in Figure 4.8 for a selected set of set-back distances extending to 200 m. By examining the data for this analysis one can estimate the risk reduction possible given an existing set-back of 30 m, which is given below:

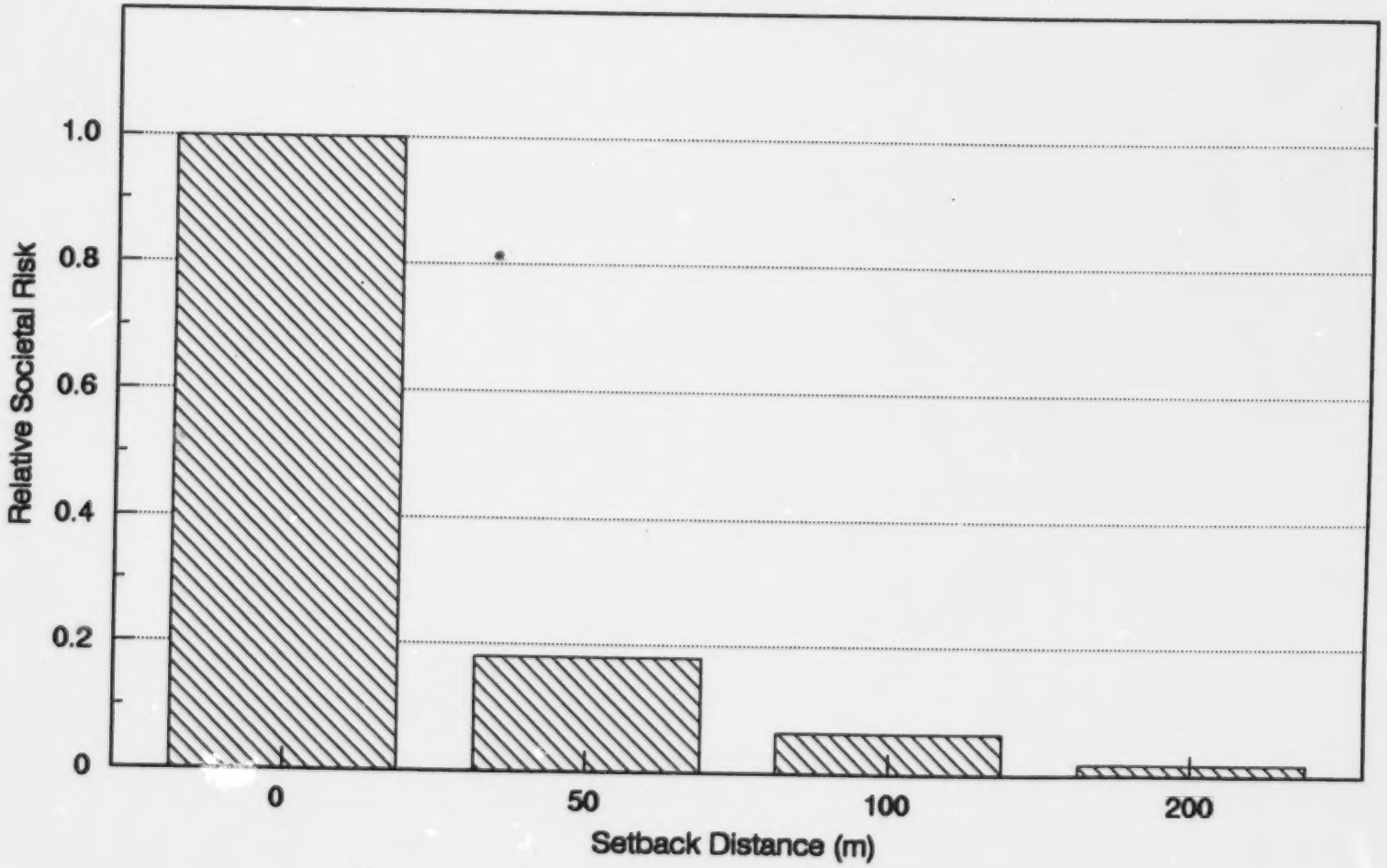
Set-back (m)	40	50	60	70	80	90	100	150	200
Reduction in Societal Risk (%)	23	40	50	59	66	72	76	90	94

Note: Results are for an idealized case along Segment 1.

Thus, a 50 m set-back gives an estimated 40% reduction in risk over a 30 m set-back, wherease a 100 m set-back would likely produce a 76% reduction. These results indicate substantial reduction in societal risk are possible through the implementation of set-backs.

The foregoing results on set-backs and risk reduction apply to rail traffic accidents involving release of DGs which is the primary focus of this study. Separate consideration was given to the public risks of a derailed train physically impacting buildings along the rail line. An analytical approach was developed for this study and was applied to the passenger corridor. Unfortunately, the limited experience with the approach, the limited nature of the input data used and the lack of corroborating data to support the results does not provide for sufficient confidence to be placed on the results. Therefore, they have not been used in considering potential risk reductions from alternate set-backs.

FIGURE 4.8
Relative Societal Risk for Differing Setbacks
Along Segment 1



5 RISK MANAGEMENT CONSIDERATIONS

The main objective of the present study is to assist the City's Planning and Development Department in its examination of suitable land-use regulatory measures for rail corridors, which incorporate public risk considerations. The objective of this section of the report is to:

- provide estimates of costs of alternate set-back distances and examine the relationship between risk reduction and cost for these set-backs;
- provide a qualitative indication of other forms of risk mitigation; and
- make recommendations for risk reduction, particularly with respect to set-back distances, giving consideration to practices in other cities.

The subsections to follow begin with a review of some relevant studies followed by a discussion of set-back distances and associated costs for the City. The last two subsections deal with other forms of risk mitigation and recommendations.

5.1 REVIEW OF RELEVANT STUDIES

A review of studies pertaining to the foregoing objectives was undertaken and inquiries were made with various municipalities regarding their related activities. Urban areas, in addition to Toronto, for which relevant information was obtained include:

- City of Regina;
- City of Calgary;
- Greater Vancouver Area;
- City of Seattle; and
- City of Denver.

The relevant aspects of these studies or activities are briefly described below.

5.1.1 City of Regina

By the end of 1983, the City of Regina had commenced the planning for modification of its rail network (City of Regina, 1983). It then proceeded to assess Phase I which consisted of removing the CN tracks and the CN railyard from the City. By so doing, the societal risk was estimated by DelCan to be reduced by 2% from one fatality every 2.5 years. It forecast that Phase II (i.e., removal of the CP tracks and the CP railyard) would have a much greater effect on societal risk. Concord (1984) determined a worst case value for societal risk that was based on the failure of a railcar of anhydrous ammonia. The overall risks estimated were:

- existing system — 1 fatality every 61 years
- system after Phase I — 1 fatality every 275 years

The main feature of this plan of restructuring the rail network was to prevent the future cost of maintaining a safe and efficient system. Relocation costs were estimated as approximately equal in value to the future costs which would arise from modifications required to render the system acceptable to the City.

One recommendation from a hearing conducted by the Canadian Transport Commission was that an environmental board should be set up to oversee the implementation of mitigative recommendations. Attention was directed to the inadvisability of installing noise barriers 4 to 5 m in height. They were regarded as effective for noise reduction to approximately 50 m only. Their effect at 300 m was deemed to be insignificant.

The findings of the study led to the following recommended buffer zones for residential development:

- mainline track: 300 m
- railway yards: 350 m

These values were based primarily on the abatement of noise and it was indicated that other land uses should be permitted within the buffer zone. It should be noted that the recommendations were not based on consideration of the risks from rail transport. A hearing was conducted by the Canadian Transport Commission regarding these buffer zones and it was decided that they were reasonable for residential development. Recent contact with officials in the City of Regina revealed that a municipal by-law stipulating these buffer zones has been in force for the past two years.

5.1.2 City of Calgary

An analysis of risk to the public in Calgary from the transportation of DGs by rail was undertaken (Jordaan *et al.*, 1983). Special attention was given to chlorine and ammonia transport which were considered the dominant hazards. The annual societal risk was estimated to be one fatality every ten years (0.1 fatalities/year). It was determined that this risk could be reduced for the cost indicated:

- 45% reduction $ 16 M
- 83% reduction $220 M

It was recommended that such reductions could be achieved by the following improvements:

- reduction of the amount of road-rail interaction;

- restriction of movement of DGs to specific corridors that can be easily controlled in the event of an accident;

- rerouting DGs to preferable corridors, relocation of trackage and regulation of growth around the rail corridors;

- improvement of growth around the new corridors; and

- construction of new by-pass rail lines.

Attention was also directed to the Railway Transport Committee's recommendations relating to:

- increasing awareness of safety;

- reducing speed; and

- undertaking gateway inspections prior to haulage of DGs through densely populated areas.

Set-backs were not included among the recommendations and the majority of the outlay on risk reduction is for construction of new corridors and elimination of level crossings.

5.1.3 Greater Vancouver Area

In order to study the transportation of DGs in the Greater Vancouver Area, a Task Force was constituted from personnel at federal, provincial and regional levels. The Task Force was supported by working groups that represented all of those who were either interested or involved in the transportation of DGs in the Lower Mainland.

In the extensive report that was produced, the major area of quantification related to hazard. This was expressed as "hazard radius (reach)" (i.e., the extent of effect

from releases of some 24 materials from "standard-sized containers"). The analysis of risk was qualitative to semi-quantitative and consequently no estimates of individual or societal risks were made.

In the report, attention is drawn to a number of topics that are recommended for further study and/or action. These are methods of risk-mitigation and amongst them are:

- rerouting and optimisation of routing of DGs;
- all aspects of emergency response; and
- increased inspection of fixed facilities and rolling stock on the railways.

There was no detailed consideration or recommendation for set-back distances as a means of risk mitigation.

5.1.4 Greater Toronto Area

Since the Mississauga train derailment of 1979, there have been a number of studies relating to the safety of dangerous goods rail transportation through the Greater Toronto Area (GTA). No attempt is made here to summarize all of this work and only selected material of specific reference to the main objective of this present study is addressed below under separate headings.

Burton and Post Study

A preliminary assessment of risk in the Metropolitan Toronto area from DG rail transport was reported on by Burton and Post (1983). This study applied qualitative to semi-quantitative analyses to assess relative risks within the rail network; no quantitative estimates of individual or societal risk were made. The CP North Toronto and Galt subdivisions were identified as presenting the highest risks, relative to other rail lines in the rail network.

While no quantitative estimates of risk reduction were made, recommendations were given on ways of reducing risk which included rerouting of special dangerous goods along the CN York subdivision and increased train inspections at gateways (also expected to reduce train speeds).

It was also recommended that the municipalities take steps to keep residences back from rail lines. This report recognized the need for a study/document on the subject of risk mitigation through the use of set-back distances. It was suggested that while it may be too late to implement set-back policies for existing rail corridors in densely populated areas, such policies must be implemented for new developments.

CN/CP Policy on Set-Backs

In 1983, Canadian National and Canadian Pacific Railways prepared a joint proposal for a provincial (Ontario) policy on environmental protection for new residential development adjacent to railways (CN/CP, 1983). To reduce public exposure to noise and vibration, a combination of set-backs and either a berm or combination of a berm and a fence were recommended as shown in Table 5.1.

TABLE 5.1

Dimensions of Set-Backs, Berms and Fences Proposed by CN/CP

Classification of Line	Minimum Set-Back (m)	Minimum Berm Height (m)	Minimum Total Height Above Top of Rail (Berm and Fence*, m)
Principal main	30	2.5	5.5
Secondary main	30	2.0	4.5
Principal branch	15	2.0	4.0
Secondary branch	15	2.0	2.0
Tertiary branch	15	None	None

* Fence to be without openings, constructed of durable material weighing not less than 20 kg/m^2.

It was also suggested that these arrangements "would minimize the possibility of railway derailment, collision or spillage affecting nearby residents".

DelCan Buffer Study

A study undertaken by DelCan (1988) for the Toronto Area Rail Transportation of Dangerous Goods Task Force dealt directly with the issue of buffers or set-back distances from rail lines. While the study area was the Greater Toronto Area, two of the locations considered as case studies were within the City limits.

This study defined a buffer zone as an "area of land which will provide sufficient set-back to protect sensitive land uses and it will accommodate land uses compatible with railway operation". Land uses considered sensitive include residential and institutional. Compatible land uses included: open space, low density industrial or commercial uses. The buffer setback distances that were selected for analysis were based on the Regina study (refer to Section 5.1.1) and included 100, 200, 250 and 300 m. The reduction in affected population due to

the implementation of set-back was used as an indicator of reduction in public risk.

The study cost estimates for buffer implementation, which are given in Table 5.2, are based upon the assumption that the land-use mix of the parcels of land examined are uniform along the main freight corridor.

TABLE 5.2

Costing by DelCan for Buffer Implementation for Trackage Shown

Location	Costs Based on 600 m of Trackage* for Various Set-Backs (m)				Costs Based on Main Freight Corridor** for Various Set-Backs (m)			
	100	200	250	300	100	200	250	300
Dupont/Dufferin	78.5	90.7	97.9	109.5	1,235	1,425	1,520	1,710
Yonge/Bayview	53.7	110.7	143.9	124.3	846	1,710	2,280	2,755

* Total value of property affected ($ millions)
** Total value of property affected ($ millions) for corridor (length = 9.5 km)

5.1.5 Central Puget Sound Region/City of Seattle

Societal risk related to the transportation of DGs by both road and rail has been estimated for the Central Puget Sound Region (CPSR) by Andrews *et al.* (1981). The major findings of the investigation that are pertinent in the present context are:

- Road and rail contribute equally to total societal risk.
- Dominant sources of risk are:
  - LPG for tank trucks; and
  - chlorine for rail cars.

- Total estimated societal risk in the CPSR was estimated at one fatality every 11 years (.091 fatalities/year).

- The average individual living within 3 km of a transport route has an estimated annual risk of 1 in 10 million of being killed due to transportation of DGs. The total value in the U.S.A. for chlorine and LPG is cited as 1 in 9 million.

No specific recommendations were made relating to the size of set-backs; the City of Seattle uses railway guidelines. However, attention was drawn to the following forms of risk mitigation:

- reduction of consequences by improvement in emergency response;
- improvements to the integrity of containers;
- rerouting of DGs away from the City; and
- transfer of DGs from open tracks near the waterfront to tunnel tracks.

Haulage of DGs is restricted to the period from 22:00 h to 04:00 h.

5.1.6 City and County of Denver

A risk assessment and risk management study for hazardous materials railroad transportation was undertaken for the City and County of Denver (Woodward-Clyde Consultants, 1987). The project produced an assessment of risk to the public from transportation of hazardous materials by rail, an examination of emergency response plans and capabilities to respond to such accidents and an evaluation of risk management alternatives. This study is considered to be the most significant study of those for other cities identified and reviewed in this report, in relation to the present investigation for the City of Toronto.

The study considered the redevelopment of the Central Platte Valley (CPV) area adjacent to the central business district of Denver from the traditional industrial use with extensive railroad facilities to one involving commercial, residential and recreational land uses. This involved the relocation of most of the railroad facilities out of the CPV although a new consolidated mainline corridor remained within the CPV for through traffic.

This investigation is of particular interest to the present study since quantitative estimates of individual and societal risks were made. The baseline societal risk estimates (prior to risk management actions) are given below:

Area	Societal Risk Estimates (Fatalities/Year)		
	Current Development	Future Development	Difference in %
CPV Alone	0.028	0.039	41
Entire City	0.267	0.278	4

The increases in baseline risks were due to the increased population densities associated with redevelopment. By using the future development, societal risk estimates of 0.278 fatalities per year for the entire City of Denver and Denver's approximately one-half million resident population, a City-wide average individual risk of 0.56 chances in a million per year was estimated.[1] These risk estimates were considered to be relatively small compared to other "every day" risks borne by Denver residents. It was also estimated that a significant number of people would be exposed to individual risk levels greater than one in a million per year. This risk level was "considered to be worthy of attention and mitigation where feasible".

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1 *This compares with the present study's estimate for the average individual risk in the City of Toronto of 0.5 chances in a million per year (based on a societal risk estimate of 0.32 fatalities per year and an average population of about 608,000 for 1984-86).*

While individual risk levels greater than one in a million were estimated for the future development, the maximum individual risk did not exceed 10 in a million.

Most of the risk was attributed to toxic vapour plumes which can result from the spill of non-flammable compressed gases (e.g., chlorine and ammonia). Also, a very large fraction of the societal risk was attributed to low dispersion atmospheric conditions which are most frequent during night time and early morning.

A range of alternative risk management actions were evaluated, including capital improvements (e.g., grade separation), railroad operations (e.g., improved training), regulatory actions (e.g., reduced train speeds and City inspections), alternative for redeveloping the CPV area (e.g., drainage controls, barriers, set-back requirements) and emergency response plans and capabilities.

Analysis of risk reduction potential from set-backs was based on individual risk only which showed that they could significantly reduce risks. A set-back of 30 m was estimated to reduce risk levels to less than one in a million and the report states that "considering the desirability of keeping the maximum individual risk indices below the 1×10^{-6} level (one in a million level), a 30 m set-back appears to be advisable. Set-backs were considered a feasible and attractive measure to reduce risk which led to a recommendation for a 30 m set-back. Improved security (confined with fencing), emergency response time and noise abatement were considered additional benefits of set-backs.

Recent contact with officials in the City of Denver indicates that a 30 m set-back has been implemented and no buildings occupied by humans on a regular basis are allowed within the 30 m set-back zone. If buildings (e.g., parking garages) were to be built within the 30 m set-back, special approval would be required and special provision should be made, such as the use of solid fire and explosion-

resistant walls as barriers and ventilation designs which limit exposure on the railroad side to toxic gases.

Other recommendations of this study of interest in the present context include:

- land-use restrictions on the location of new facilities near the tracks which themselves handle hazardous materials or attract high density populations;

- use of barriers in conjunction with other land-use and development concepts (barriers were estimated to reduce risk of explosions and fire by about 20% in the CPV); and

- use of drainage controls involving shut-off valves and possibly sumps on storm drainage sewers, to effectively limit the size of a spill.

The foregoing material only highlights some of the information contained in the Denver study which was comprehensive and detailed.

5.2 SET-BACKS AND ASSOCIATED COSTS

This section addresses the costs associated with alternative set-back distances. The cost analysis was conducted by the firm of Marshall Macklin Monaghan (MMM) whose report is contained in the Appendix B. The following provides a brief summary of this analysis and examines the relationship between risk reduction and costs of various set-back distances along the main freight corridor.

The basis of MMM's methodology was to determine the building potential and subsequent reduction in land value per linear meter of track for three set-back distances - 10, 30 and 50 m - at ten selected locations along the main freight corridor. Estimates were also made for 100 m set-back distances based on only

two locations. Cost estimates were based on three land-uses: industrial, residential and commercial. The land valuations are based on an analysis of the expected market value of the property from putting it to its highest and best use. Therefore, the estimated costs should be viewed as "lost opportunity costs" to the landowners.

The analysis was based on data provided by the City on total area bounded by the various set-backs. The total length of trackage obtained from this analysis indicated 7,016 m, which is not consistent with the rail data of 9,560 m of track along the main freight corridor. The land value analysis was based on 10,750 m of flankage (or 5,375 m of track length) for industrial, residential and commercial land uses. Other land-uses, such as recreational, comprise those lands which occupy the remaining trackage of 1,641 m (7,016 - 5,375 m) in the City's data base.

The ten locations used for specific economic analysis were selected from the 16 locations of fixed hazardous facilities and key concern public facilities discussed in Section 2. Table 5.3 lists these ten locations along with the applicable land-use zoning.

TABLE 5.3

Properties Used in Cost Estimates for Set-Backs

Site	Zoning
Inmont Canada	Industrial
National Rubber - Symington	Industrial
Anchor Cap	Industrial
Nacan Products	Industrial
The Ports	Commercial
Welder's Supply	Commercial
St. Rita's School	Residential
George Brown College	Residential
Whitney Public School	Residential
Christie Gardens	Residential

The cost estimates for various set-backs along the entire main freight corridor are given in Table 5.4. It must be noted that these are estimates based on the assumption that the industrial, residential and commercial property values actually determined are representative of property values along all three segments of the main freight corridor. This is a reasonable assumption for all but the commercial land value analysis for the 100 m set-back, which was based on a site (The Ports) which is considered to have a higher value than would be typical for the corridor. Therefore, the total estimate in this case is on the high side.

TABLE 5.4

Cost Estimates[1] for Set-Backs Along the Main Freight Corridor

Set-Back Distance (m)	Cost ($ millions) by Land Use			
	Industrial	Residential	Commercial	Total
10	0	0	0	0
30	7	52	104	163
50	17	118	366	501
100	62[2]	238[3]	1,406[2]	1,751

1 Estimates are based on valuations of 10 properties (except for those noted ... 2. below) which are assumed to be representative of land-use along the entire corridor, using 7,016 m as the length of trackage.

2 These values are based on only one site for each land-use type, which again are assumed to be representative of land-use along the entire corridor.

3 This is a "guesstimate" based on the progression of residential costs.

Then, from Table 5.4, the average cost per kilometre of travel of the three set-back distances, based on 7,016 m of track, is as follows:

Setback (m)	Approximate Average Linear Cost ($ million per km track)			
	Industrial	Residential	Commercial	Total
30	1.0	7.4	14.8	23.2
50	2.4	16.8	52.2	71.4
100	8.8	33.9	200.4	249.6

Extending the analysis to each of the three segments of the main freight corridor provides the cost estimates given in Table 5.5. It should be noted here that since the total length of trackage from summing the lengths of these segments is 9,560 m, total costs for each set-back in this table are not the same as in Table 5.4, which is based on 7,016 m as the length of the corridor from land-use data.

TABLE 5.5

Cost Estimates[1] for Set-Backs Along Rail Segments 1, 2 and 3 of the Main Freight Corridor

Segment	Segment Length (km)	Set-Back Distance (m)	Cost ($ millions)			
			Ind	Res	Com	Total[2]
1	1.82	30	2	13	27	42
		50	4	31	96	130
		100	16	62	365	454
2	0.88	30	1	7	13	20
		50	2	15	46	63
		100	8	30	176	220
3	6.86	30	7	5	102	159
		50	17	115	358	490
		100	60	233	1,375	1,712
Total Corridor	9.56	30	9	71	142	222
		50	23	161	499	683
		100	85	324	1,916	2,386

1 These values are derived by multiplying the length of each segment (shown in brackets) by the cost per kilometre of trackage.

2 These totals differ from those of Table 5.4 since they are based on 9,560 m of actual trackage versus the 7,016 m of trackage used for the land valuations analysis of Table 5.4.

Clearly, costs of implementing set-backs in the highly developed areas bounding the main freight corridor are very high, with 30 to 100 m set-backs costing, respectively, $222 million to $2.4 billion for the entire corridor (or $23 to $250 million per kilometre of track).

As discussed in Section 4.4, set-backs could result in significant reduction in levels of risk. These potential reductions in risk will now be examined in relation to set-back costs. Using the risk analysis data from which Figure 4.2 and Table 4.3 of Section 4 were derived, the levels to which maximum individual risk could be reduced with 30, 50 and 100 m set-backs are determined as shown in Table 5.6. Although levels of risk remain at or above 10 in a million, even with a 100 m set-back, except for rail segment 3, significant reductions in risk are afforded by these set-backs. Set-backs of 30 to 100 m would reduce levels of individual risk that could exist with a 0 m set-back by 25 to 88%.

From Table 5.7, the merits of 50 and 100 m set-backs over a 30 m set-back are shown in terms of percentage reduction in maximum individual risk levels. A 100 m set-back would reduce risk levels along the main freight corridor by more than 60% over a 30 m set-back. Also, in the analysis and discussion of Section 4.4, it was shown that 40 to 76% more reduction in societal risk was likely by implementing 50 to 100 m set-backs over a 30 m set-back. However, the data of Table 4.6 indicated that to reduce maximum individual risk levels to 10 in a million per year along segments 1, 2 and 3 would require set-backs of 98, 142 and 59 m, respectively, and to reduce risk levels to 1 in a million per year, set-backs of 324,450 and 270 m, respectively, would be required. Given the cost estimate of $2.4 billion for a 100 m set-back along the main freight corridor, which is greater than the costs estimated ($1 to 2 billion) to build and operate a completely new rail corridor to the north of Toronto for rerouting of DGs (IBI, 1988), it is highly unlikely that set-back distances of 100 m or larger could be seriously considered along this corridor.

TABLE 5.6

Levels to Which Maximum Individual Risk Could be Reduced With 30, 50 and 100 m Set-Back Distances

Set-Back Distance* (m)	Maximum Individual Risk by Segment (chances in a million per year)		
	Segment 1	Segment 2	Segment 3
0	85	115	35
30	43	86	16
50	20	53	14
100	10	21	4.3

* Set-back starts at edge of railway right-of-way, about 10 m from rail line.

TABLE 5.7

Percentage Reduction in Maximum Individual Risk Levels From 30 m to 50 and 100 m Set-Backs

Set-Back Distance* (m)	Reduction in Risk (%) From that at 30 m		
	Segment 1	Segment 2	Segment 3
50	53	38	13
100	77	60	69

* Set-back starts at edge of railway right-of-way, about 10 m from rail line.

Therefore, the costs and potential risk reduction of other risk mitigation measures, which could be used in conjunction with set-backs of the order of tens of metres, should be carefully examined as alternatives to large set-back distances, as the sole means of risk reduction along this highly developed urban rail corridor.

5.3 OTHER FORMS OF RISK MITIGATION

There are forms of risk mitigation other than set-backs that should be considered in the context of risk exposure from rail corridors. These measures are briefly discussed here on a qualitative basis. The methods include:

- land-use restrictions;
- barriers or barricades;
- tunnels;
- time-of-day scheduling;
- rerouting;
- speed restrictions;
- improved training of rail and emergency response personnel;
- inspection programs on rail cars;
- better (i.e., more frequent) inspection of rail corridors in terms of track and rail bed conditions;
- drainage controls; and
- increased protection at level crossings.

5.3.1 Land-Use Restrictions

In addition to set-backs as a land-use restriction measure, considerations can be made to the type of land-use which can be employed near existing and proposed rail corridors. Decisions can be made, particularly with respect to future development, on the extent of population exposed and public risk can thereby be controlled through appropriate zoning regulations.

The Denver and DelCan studies have addressed this measure. Sensitive land-uses such as institutional buildings, residential areas or other high density facilities should be restricted adjacent to the tracks. Less sensitive land-uses such as low density industrial development and parkland would be more suitable near rail lines. Restrictions on locating hazardous facilities near rail lines should be a consideration. However, due to the use of railroad transportation for supply of chemicals, these same facilities may desire to be located near rail lines, producing a land-use conflict.

5.3.2 Barricades

Barricades are high strength walls or berms which have a low-to-moderate cost and reduce risk in the following ways:

- reduce the severity of or eliminate physical impact with buildings; and
- limit the extent of some aspects of fire and explosion hazards (helps reduce near-field effects).

Barricades suffer from disadvantages such as:

- limited effectiveness against toxic plumes such as chlorine; and
- make accessibility to rail corridors more difficult.

In the Denver study, it was assumed that barriers would mitigate all consequences from train accidents except those relating to vapour plumes or rising fireballs. The analysis indicated a 17% reduction in future risk for the area would result. They were recommended in conjunction with other land-use and development concepts.

5.3.3 Tunnels

Tunnels have been implemented in Seattle. Benefits from tunnels include:

- complete shielding of the exposed population from the risk; and
- reduction of noise and vibration associated with rail corridors.

This approach suffers from the following disadvantages:

- reliance on a ventilation system to remove exhaust from the trains;
- difficult access by emergency response personnel to the train in the event of an accident;
- the geometrical consideration of a tunnel can actually enhance the hazard (e.g., run-up to detonation); and
- expensive the construct and maintain.

5.3.4 Time-of-Day Scheduling

In the Denver study, time-of-day scheduling of non-flammable compressed gases (e.g., chlorine) was considered since these DGs account for a large fraction of the overall risk and that risk is highly dependent on day versus night time atmospheric dispersion conditions. This analysis indicated a reduction of 86% in societal risk by restricting these DGs to day-time transport only. This analysis was questioned in terms of the effectiveness of night versus day transport when factors not considered, such as 1) emergency response; 2) chemical spill suppression; and 3) population evacuations are accounted for.

However, actual regulations along these lines were judged to be both procedurally and operationally impossible.

The City of Seattle, we have been informed, has chosen to go the other way and restrict time-of-travel to the night time (10:00 p.m. to 4:00 a.m.). No documentation was received on the basis for this decision which has been implemented.

The following considerations are some of the important factors in the day versus night issue:

- Toxic plumes do not disperse very well in low wind, stable atmospheric conditions which occur most frequently at night.

- Lower visibility at night could increase confusion, making work for responders more difficult, however, the effectiveness of chemical suppression equipment may be greater due to lower winds and more stable atmospheres at night.

- If land-use is either commercial or industrial, the population density will be low at night and high during the day.

- If the land-use is residential, population densities would be highest at night.

- While people are easier to locate at night, they are more difficult to evacuate because of logistical/communication problems or simply due to disorientation and confusion.

5.3.5 Rerouting/Relocation

Directing the movements of DGs along alternative routes (e.g., where the population densities are lower) is a common consideration. Benefits include:

- new routes can be established which move the hazard away from high to low population density areas, thus reducing societal risk; and

- a method in which the risk of alternate routes are readily measurable by risk analysis (i.e., determination of the relative risks of DG traffic routing through existing or proposed rail routes presently evaluation of optimum routine for risk reduction).

The disadvantages in this approach include:

- high capital costs associated with establishing new routes;

- rerouting of DGs may pose operational problems (i.e., getting the DGs to and from desired locations) as well as adding to operating costs; and

- alternatives for rerouting which transfer risk to other areas are generally associated with the "Not In My Back Yard" (NIMBY) syndrome.

A study by IBM (1988) for the Toronto Area Rail Transportation of Dangerous Goods Task Force identified alternative routes and operating strategies and examined their feasibility.

5.3.6 Speed Restrictions

Restricting the speed of DG trains in urban areas is also a common consideration. The general opinion is that, in relative terms, trains travelling at low speeds would

lead to less severe consequences, should an accident occur, than trains travelling at high speeds. On the other hand, it is not clear how the likelihood of an accident occurring varies with train speed. As risk has been defined as the product of the consequences and likelihood (expected frequency) of an accident, it is important to consider both factors in any attempt to examine the relationship between train speed and risk to the public. To the authors knowledge, no definitive quantitative study has been conducted to-date on this problem. This appears to be an area requiring further research.

5.3.7 Improved Training and Availability of Emergency Response Personnel

Concern was raised in the Vancouver study and Denver study about the level of training and availability of emergency response personnel. Having properly trained and knowledgeable personnel who can respond promptly and effectively to an emergency is essential to mitigate risk to the public. Pertinent considerations include:

- training programs;
- emergency response exercises to test the effectiveness of emergency response and evacuation capabilities;
- coordination of the actions of all departments involved in the emergency; and
- the status of the emergency preparedness of local industry.

5.3.8 Inspection Programs

Inspection programs are an essential part of preventive maintenance. These concerns have been raised in the Vancouver study. In the report, attention is drawn to the inspection of rail cars and particularly of container integrity. As

well, frequent inspection of the track using a Sperry car is effective in reducing the accident probility by maintaining the track in good coqdition. The ties and the fixed plant of the rail corridor also require similar inspection and maintenance.

5.3.9 Drainage Controls

Drainage controls help to limit the extent of the spill. In the Denver study, recommendations were made, which included shut-off valves and sumps in the storm drainage sewers, based on estimates that future risk levels could be reduced by over one-third. They are low-to-moderate cost measures with little conflict with land-use and rail operations.

5.3.10 Increased Protection at Level Crossings

Increased protection at level crossings may involve any of the following features:

- improvement of sight lines;
- automatic warning and barrier devices; and
- provision of overpasses (grade separators).

While important for other public safety reasons, these measures were not considered to be effective in reducing risk from DGs in the Denver study.

6 FINDINGS

This study assessed the risk to the public from the potential release of hazardous substances from railroad operations and facilities in the City of Toronto. The primary purpose of this report is to provide guidance to the City for the establishment of set-backs and suitable land-use measures to manage and mitigate risk to the public along DG rail corridors.

The major findings of this study can be summarized as follows:

- The societal risk or the overall risk to the public from DG rail transport within the City was estimated at 0.322 fatalities per year (or 1 fatality per 3.1 years). A similar study for the City of Denver in 1987 estimated a comparable societal risk level of 0.278 fatalities per year (or 1 fatality per 3.6 years). These levels of societal risk, when compared to common societal risks, were shown to be relatively small for both cities. The average individual risk of fatality for the City of Denver, with a population of approximately 500,000 was given as 0.56 chances in a million per year which is also comparable to the estimate of 0.5 chances in a million per year for the City of Toronto, with a population of about 608,000.

- It was estimated that the three rail segments comprising the main freight corridor (the CP Galt and North Toronto railway subdivisions) account for 41% of the societal risk due to DG rail transport in the City.

- Segments 2.1 and 3.1, were found to pose the highest and second highest levels, respectively, of societal risk by a significant margin (about a factor of two or more), when compared to the other rail segments in City's rail network. The societal risk rate along the highest risk segment is about 90 times higher than that along the lowest risk segment (segment 13).

- The risks to the public from DG transport along the main freight corridor (segments 1, 2 and 3) are significantly higher than those posed by the other DG rail lines (segments 4-13) in the City.

- Estimated values of maximum individual risk of fatality are below 100 chances in a million per year (a relatively high risk level comparable to the individual risk of falls in the City) for all DG rail lines except for the main freight corridor, where within 30 m of Segment 2, levels of individual risk reach 100 to 115 chances in a million per year.

- Only rail segments 1 to 4 pose individual risk of fatality of greater than 10 chances in a million per year at the edge of the railway right-of-way (~ 10 m from the rail line).

- All rail segments pose individual risk of fatality of greater than 1 chance in a million per year at the edge of the railway right-of-way.

- The use of set-backs, as a risk mitigation measure, were shown to provide significant levels of risk reduction. Compared to a set-back of zero metres (roughly 10 m from rail line), set-backs of 30 to 100 m were estimated to reduce maximum levels of individual risk by 25 to 88%, along the main freight corridor.

- Given the existence of 30 m set-backs, the reduction in maximum individual risk was estimated to be 13 to 77% through implementation of 50 to 100 m set-backs along the main corridor. The corresponding percentage reductions in societal risk were estimated to be 40 to 76%.

- The lost opportunity costs to implement 30 to 100 m set-backs for all development along the entire main freight corridor were estimated at about $222 to $2.4 billion, respectively, based on land valuations for each type of development - industrial, residential and commercial.

- The set-back lost opportunity costs for the entire main freight corridor by development type are as follow:

SET-BACK DISTANCE (M)	COST ($ MILLIONS)			
	INDUSTRIAL	RESIDENTIAL	COMMERCIAL	TOTAL
30	9	71	142	222
50	23	161	499	683
100	85	324	1,916	2,386

A risk management decision making process needs to weight three principal factors: risk to the public, economic considerations and socio-political considerations. This study has provided: estimates of immediate mortality risk but not sub-lethal risks to the public; approximate costs of only one risk mitigation measure, set-backs, but not other economic considerations which would be associated with accidents involving fatalities, non-lethal effects, evacuations, environmental clean-up, etc., and no assessment of socio-political considerations.

For the authors of this report to make firm recommendations to the City regarding the sizes of set-backs that should be implemented would not be appropriate, as this would require value judgements to be made on the levels of risk which would be acceptable to the public. These are social value judgements that can only be made by the public or their elected representatives. The report has documented the basis for the risk estimates and the uncertainty about them along with some common city risks and risk criteria from other jurisdictions to assist City officials and other interested parties in evaluating the acceptability of the estimated risks.

In order to satisfy the requirements of this study and provide recommendations for risk reductions with respect to set-back distances, without making the above noted value judgements nor making assumptions as to the risk criteria that City Council might adopt, a range of options has been prepared for the main freight corridor in consultation with the City's Planning Department. They are as follow:

OPTION 1A: 30 METRE SETBACK FROM RIGHT-OF-WAY FOR RESIDENTIAL DEVELOPMENT AND PLACES OF ASSEMBLY (I.E., SCHOOLS)

BENEFITS:

- Reduces maximum levels of individual risk of fatality per year for:
  - Segment 1 by 49% from 85 to 43 chances in a million
  - Segment 2 by 25% from 115 to 86 chances in a million
  - Segment 3 by 54% from 35 to 16 chances in a million
- Consistent with existing railway policy (based on noise and vibration considerations).

COSTS: Roughly $76 million for the entire corridor.

OPTION 1B: 30 METRE SETBACK FROM RIGHT-OF-WAY FOR ALL DEVELOPMENT (INDUSTRIAL, COMMERCIAL, RESIDENTIAL)

BENEFITS:

- Reductions in individual risks same as for Option 1A.
- Greater reductions in societal risk than for Option 1A.

COSTS: Roughly $222 million for the entire corridor.

OPTION 2A: 50 METRE SETBACK FROM RIGHT-OF-WAY FOR RESIDENTIAL DEVELOPMENT AND PLACES OF ASSEMBLY

BENEFITS:

- Reduces maximum levels of individual risk of fatality per year for:
  - Segment 1 by 76% from 85 to 20 chances in a million.
  - Segment 2 by 54% from 115 to 53 chances in a million.
  - Segment 3 by 60% from 35 to 14 chances in a million.

COSTS: Roughly $161 million for the entire corridor.

OPTION 2B: 50 METRE SETBACK FROM RIGHT-OF-WAY FOR ALL DEVELOPMENTS

BENEFITS:

- Reductions in individual risk same as for Option 2A.
- Greater reductions in societal risk than for Option 1A.
- Reduces societal risk by roughly 40% over Option 1B (only if no development within 50 m).

COSTS: Roughly $683 million for the entire corridor.

OPTION 3A: 100 METRE SETBACK FROM RIGHT-OF-WAY FOR RESIDENTIAL DEVELOPMENT AND PLACES OF ASSEMBLY

BENEFITS:

- Reduces maximum levels of individual risk of fatality per year for:
  - Segment 1 by 88% from 85 to 10 chances in a million.
  - Segment 2 by 82% from 115 to 21 chances in a million.
  - Segment 3 by 88% from 35 to 4.3 chances in a million.
- Greater reduction in societal risk than for Option 2A.

COSTS: Roughly $324 million for the entire corridor.

OPTION 3B: 100 METRE SETBACK FROM RIGHT-OF-WAY FOR ALL DEVELOPMENT

BENEFITS:

- Reductions in individual risk same as for Option 3A.
- Greater reductions in societal risk than for Option 3A.
- Reduces societal risk by roughly 76% over Option 2B (only if no development within 100 m).

COSTS: Roughly $2.4 billion for the entire corridor.

With regard to these options, it will be noted that no quantitative comparisons of societal risk reductions were made for cases other than "all development". Risk analyses were done using total population data only, that is, no analyses were done for residential, industrial and commercial populations on a separate basis. Such analyses would be possible contingent upon disaggregation of the population statistics.

Also, a no set-back option has not been presented, given that some parts of the main freight corridor have estimated levels of individual risk of fatality of greater than 100 chances in a million per year. Such levels are generally considered high and other jurisdictions appear to be adopting 10 chances in a million as an upper bound on acceptable individual risk. Consensus appears to be forming that one chance in a million per year of fatality represents the level of individual risk below which risks are considered trivial or not significant. This level has thus become widely accepted as the desirable level to achieve. In the City of Denver study, for example, set-backs of 30 m were recommended to reduce risks to this level.

With regard to segments 4 through 13, a set-back of 30 m may be a suitable set-back for the City to consider since it would reduce levels of individual risk to generally well below 10 chances in a million per year and is consistent with railway policy. Cost estimates for set-backs along these segments was not a requirement of this study.

However, for the main freight corridor, it is recommended that other risk mitigation measures be seriously considered in addition to set-backs, which even at 100 m would not reduce maximum levels of individual risk below 10 chances in a million along the entire corridor. The first measures to consider are those that are directly within the control of the City such as land-use restrictions, barriers and drainage controls. These measures were recommended in the Denver study along with set-backs. A detailed examination of these and the other risk mitigation measures would need to be undertaken before site specific recommendations or decisions could be made.

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APPENDIX A

TERMS OF REFERENCE

FOR

RISK ASSESSMENT/MANAGEMENT STUDY

FOR RAIL CORRIDORS IN THE CITY OF TORONTO

JUNE 1988

BACKGROUND

On May 6, 1988, City Council passed the following motion requesting the Planning and Development Department to proceed with a risk assessment/management study for rail corridors in the City:

1. That the Planning and Development Department draft Terms of Reference for a Risk Assessment/Management Study for rail corridors in the City of Toronto; and

2. That the Toronto Area Rail Transportation of Dangerous Goods Task Force be requested to share the relevant technical information with the City of Toronto.

OBJECTIVE

The present risk assessment/management study for rail corridors in the City of Toronto is required to assist the Planning and Development Department establish suitable regulatory measures for rail corridors which incorporate public safety/risk considerations.

The intent here is to extend the large area risk assessment and management study undertaken for the Toronto Area Rail Transportation of Dangerous Goods Task Force, focusing on the specific hazards to the public posed by dangerous goods (DG) and non-DG rail traffic within the City of Toronto.

The primary focus of the study is dangerous goods rail traffic along the main freight corridor in the City of Toronto. Of secondary interest, are individual and societal risk assessments for populations within 30 m of the main passenger corridor. (see map 1 for depiction of separate study corridors).

The following comprise the terms of reference for the study. Each requirement is followed by a (P) for primary and/or (S) for secondary to denote how it fits into the context mentioned above.

In addition, an asterisk denotes that the relevant information will be the responsibility of the City of Toronto. All other tasks will be the responsibility of the consultant.

1. DATA COLLECTION, SYSTEM REVIEW AND INFORMATION ASSEMBLAGE

a) Identify selected locations of hazardous fixed facilities (i.e. industrial plants) where knock-on effects could occur. Identify quantities and types of dangerous goods handled at these facilities. (P)*

b) Obtain accurate data on current and projected residential and employment population in study area; identify key concern areas such as schools, hospitals, senior citizen residences, etc. (P)*

c) Obtain data on residential and employment populations within 30 m. of the main passenger corridor (S).*

d) Examine physical characteristics of the study rail corridors (P and S).

e) Obtain data on common risks experienced by people in the Toronto area (for comparative purposes with risk estimates of this study). (P and S).

f) Review pertinent federal, provincial & municipal studies (P and S).

g) Determine what other cities are doing on this subject (P and S).

2. RISK SCOPING

a) Identify key situations within the City of Toronto where public safety is threatened by possible rail transportation accidents and existing land uses adjacent to rail routes (P).

b) Employ a suitable risk scoping method to screen and set priorities for hazards to the public (P).

c) Prepare an interin report on hazards for which priorities have been set with recommendations on which hazards should be subject to detailed risk assessment (P).

d) Review priorized hazards with City officials and advisors to establish a major hazards list for detailed risk assessment (P) (see section 5).

3. RISK ASSESSMENT

A) Hazard and Consequence Analysis

a) Estimate through the use of recognized methods the potential hazard zones for each of the major hazards selected for detailed assessment (P).

b) Estimate the consequences in terms of potential human casualties from the immediate (acute) effects of an accident in each major hazard area. Do not analyse for sub-lethal consequences, but document in qualitative terms the potential implications (P).

B) Frequence Analysis

a) Review causes and frequencies of past railroad accidents (P and S).

b) Estimate the frequency of rial hazard accidents and non-dangerous goods accidents (P and S).

C) Quantification of Risk

a) Estimate levels of risk to the public form both DG and non-DG rail transportation accidents associated with the major hazards (P and S).

b) Provide public risk estimates in terms of individual risk, societal risk and societal risk rates along rail routes (P and S).

c) Evaluate the relative levels of risk and compare them to commonly experienced risk, particularly in the Toronto area (P and S).

d) Delineate risk zones along rail routes as a function of distance away from the railway to aid in evaluation of suitable set-back distances for land use regulatory measures (P).

4. RISK MANAGEMENT ANALYSIS

a) Estimate costs of land for alternate set-back distances and examine the relationship between risk reduction and cost for these set-backs (P).

b) Provide a qualitative indication of other forms of risk mitigation potential (P).

c) Make recommendations for risk reduction, particularly with respect to set-back distances, giving consideration to practices in other cities (P).

5. REPORTING AND PROCESS

The study will be co-ordinated by John Gladki and supervised by an advisory group made up of staff rom the City of Toronto. Three full-day meetings will be held with the consultant during the course of the study.

An interim report dealing with the risk scoping analysis will be submitted to the advisory group for review within two months of commencement. The consultant shall also submit a draft of the final report to be reviewed by the Advisory Group within eight months of commencement.

An executive summary shall be included as part of the draft and final reports and in a form for separate reproduction for public distribution. Twenty copies of the final report shall be submitted to the study co-ordinator.

The City of Toronto will be solely responsible for evaluation of the proposals and is under no obligation to proceed further with any proposal reviewed. Rights to the use of all information and materials collected and submitted will reset solely with the City of Toronto.

CONSULTANT SUBMISSION

A proposal document should be submitted to:

Mr. John Gladki
Program Manager, Policy Section
Planning and Development Department
20th Floor, East Tower
City Hall
Toronto, Ontario
M5H 2N2

No later than July 29, 1988.

The proposal should include a description of the study approach, the curriculum vitae of personnel who would be working on the study (including that of any outside consultants who may be used for particular work), a description of related experience of the firm in undertaking similar projects, the anticipated work programme and schedule, and cost. Details of the format of the final report and suitability for reproduction must be included in the proposal.

The total cost of the study will be $90,000.

MODIFICATIONS TO THE TERMS OF REFERENCE (TOR)

During the course of this study, certain changes and deviations from the Terms of Reference were made. The details of the changes and the reasons for them are outlined.

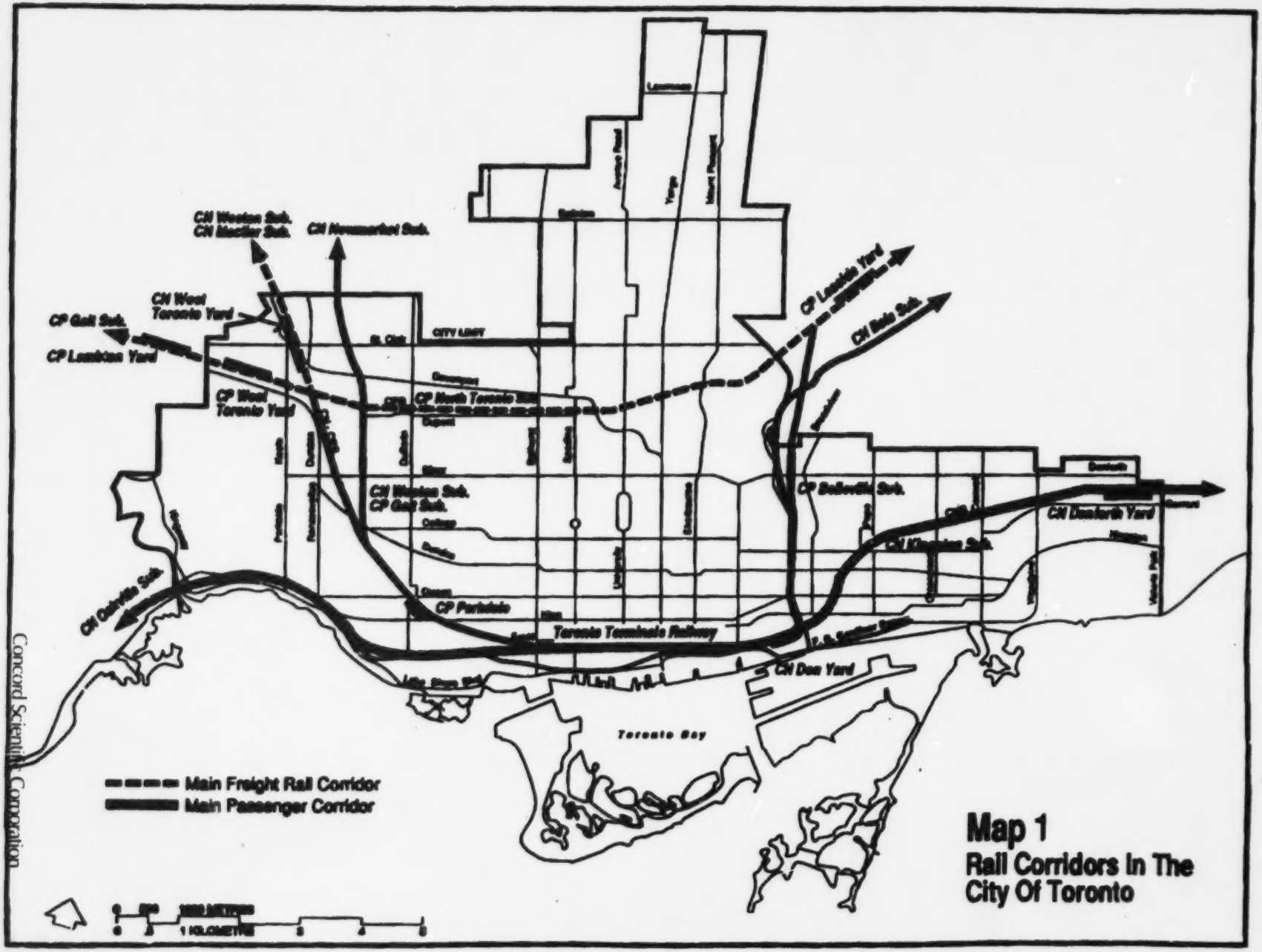
An analysis of knock-on from hazardous fixed facilities located near the main freight corridor was required. A quantitative analysis would require information on types and quantities of dangerous goods handled at these facilities (TOR, Section 1(a)). Difficulty was encountered in obtaining this data and only partial information was available. A qualitative assessment was made for ten fixed facilities, five of which handle DGs and the

other five being vulnerable facilities (eg., schools).

Projected population densities were called for in the TOR, Section 1(b). This data was not available to the study because the errors associated with making such estimates were considered unreasonably high by the Planning Department. This is especially true in regions close to the rail where future policy decisions are uncertain.

Effort was undertaken to model the risk associated with the non-dangerous goods related accidents. Physical impact with buildings and level crossing accidents were considered as the most likely events. The available techniques and data were inadequate to make a realistic estimate on this aspect of risk to the public. There are no results reported for the population located within 30 m of the passenger corridor.

The original intent for this study was to employ the 1985 DG rail traffic data base developed for the Toronto Area Rail Transportation of Dangerous Goods Task Force. This data base was revised to reflect CP's 1988 DG rail traffic which differs from the 1988 traffic, but is more representative of the current DG traffic flows. The risk analysis therefore, reflects this new data.



Concord Scientific Corporation

APPENDIX B

IMPACT ON LAND VALUES BY SET-BACKS

IN THE CITY OF TORONTO

Prepared by

Marshall Macklin Monaghan

1.0 METHODOLOGY

This section of the study details the various tasks utilized to provide an indication of the the impact on land values if buffer setbacks fronting the Canadian Pacific Railway Corridor in the City of Toronto are implemented. These techniques utilize economic real estate theory which arrives at the reduction in building potential for each buffer band.

1.1 APPROACH

The approach taken by Marshall Macklin Monaghan is to determine building potential and the subsequent reduction in land value per linear meter of track and is different from the one utilized by Royal LePage Real Estate Services, in their 1986 report. The Royal LePage Report (Study of Possible Land Uses Evaluation (North Toronto Subdivision (Canadian Pacific Railway) and Canadian Pacific Railway Agincourt Yard) basically determines the value of the rail line if used for another purpose, in terms of potential uses of the abandoned right-of-way and other adjacent lands that may become available.

The rationale utilized by Marshall Macklin Monaghan in determining the total reduction in land value by buffer setback is as follows:

- The buffer setback is to be retained by the landowner not the City of Toronto.
- Restriction of development potential by the buffers may force relocation by the landowner.
- The current utility of the landowner is not effected until the property is redeveloped.

1.2 ECONOMIC REAL ESTATE THEORY

The theory or argument used to determine each site's land value is based on the "Highest and Best Use" rationale. This theory is defined by William N. Kinnard Jr. in his book titled Income Property Valuation, Principle and Techniques of Apprising Income-Producing Real Estate, as follows:

> **Highest and Best Use.** Under informed ownership, income-producing real estate will be put to the use that will, over the appropriate investment

period, produce the highest net money income. Thus, the anticipated future benefits capitalized to a present worth figure which represents Market Value are those net income receipts anticipated from putting the property to its Highest and Best Use. Under given market conditions, this is its most probable use.

Basically speaking, the recovery of benefits is the "return" or economic reason for purchasing property. If the "return" ability of the property is reduced, then its value is reduced accordingly. From an economic view, all real estate properties are treated as an investment.

For example, if the maximum building development potential of the property is reduced by 40% by the buffer setback, then its potential to be developed under current planning guidelines is also reduced accordingly.

If this is the case, then the value of the property is reduced, as its potential to be developed to its maximum density has now been restricted by the buffer setback to the tune of 40%. This approach has been utilized in determining the reduction in land values by developable square metre of buildable area by buffer setbacks.

The following study, therefore, assess the amount of building that can be constructed on a particular parcel (for each buffer scenario) as an indication of land value.

1.3 SITE SELECTION PROCESS

Discussions were held with Concord Scientific consultants to determine the width of the buffer setbacks. Ten sites were selected as representative "case studies" from a list of sixteen potential properties. The sites were chosen based on their land use composition and overall proximity to the Canadian Pacific Railway Corridor. The sites chosen represent a cross-section of typical landuses along the Canadian Pacific Railway Corridor.

1.4 STEPS IN DETERMINING BUILDING POTENTIAL AREA

In determining the market value for each buffer setback, the properties under investigation were analyzed according to the permitted land use under the current, applicable, zoning by-law for the City of Toronto. The zoning by-law determined the

maximum total floor area when redeveloped and, therefore, corrects for the fact that the property may not now be developed to its potential.

Discussions were held with local neighbourhood planners to determine whether the current land use for each site would remain if the property were to be redeveloped.

It should be noted that since these buffers are considered for properties that currently have buildings on them, unless the City were to purchase the buffer strip, the existing buildings would remain as legal non conforming uses even if they are within the buffer area. New development would, however, not be permitted within the buffer areas.

The initial steps in the process were basically development planning oriented, concentrating on the following tasks for the ten sites reviewed:

1. Determine the lot area of the properties under review, based on site specific property data maps;

2. Draft the 10, 30 and 50 metre buffer bands on the property data maps;

3. Estimate total gross floor area (square metres) based on current land use policies.

4. Determine maximum foot print and total building area as limited by the zoning provisions (front, back and side yards), by the buffer allowance and compared this to the maximum amount of building permitted under coverage provisions.

   Where the buffer reduced the total building potential below that permitted under coverage provisions this is interpreted as a lowering of the land value as building potential is reduced.

1.5 STEPS IN DETERMINING LAND VALUE REDUCTIONS

Once the total floor area that can be developed under each buffer scenario was established for each of the ten sites, the following determined the value per developable meter of track flanked.

1. Determine the building potential lost on each site and assign a value to it as defined in Table 1.1;

2. Once the values were arrived at, they were used to calculate the reduction in building potential and, therefore, land value per metre of track and the associated costs due to the loss of buildable area.

3. The economic costs determined for each site were then averaged by land use as a "proxi" for the conditions along the total CPR Corridor. This data is summarized in Table 2.2.

TABLE 1.1

REAL ESTATE VALUE ASSUMPTIONS

1. Industrial

- representative of industrial land values along the CPR Main Freight Corridor (North Toronto and Galt Subdivision)
- $86 per developable square metre (or $8 per developable square foot).
- $600,000 - $800,000 per acre.

2. Commercial (Office)

(a) Yonge/St. Clair Area

- $1,076 per developable square metre (or $100 per developable square foot).

(b) Davenport/Dupont Area

- $538 per developable square metre (or $25 per developable square foot)

3. Residential

- $19,685 per front metre (or $6,000 per front foot)
- $90,000 per unit

The following study, therefore, assesses the amount of building that can be constructed on a particular parcel (for each buffer scenario) as an indication of land value.

For example, the reduction in building potential, at 50 metres for the Nacan site is 2,372 square metres. This figure is then multiplied by the value for developable square metre ($86), translating into $203,992. This value is then divided by the length of track

(62 metres) within the site's property boundaries to determine the reduction in total value per metre of track, which is $3,290. This calculation was performed for each of the sites.

Flankage (direct exposure by land use to the railway corridor) by land use was developed from information provided by the City of Toronto Planning Department, and is presented in the following table.

TABLE 1.2

TRACKAGE FLANKED ACROSS THE CPR CORRIDOR

Land Use	Trackage Flanked
Industrial[1)]	2,935 m
Commercial[2)]	2,878 m
Residential	4,927 m
TOTAL	**10,750 m**

1) *Includes warehousing and storage uses.*

2) *Includes office uses.*

2.0 SITE ANALYSIS AND RESULTS

This section of the report discusses the results of each setback scenario in determining building potential and reduction in land value for the ten sites reviewed and across the Canadian Pacific Railway Corridor. Profiles for each of the ten sites reviewed are situated at the end of this section.

2.1 HIGHLIGHTS

Of the ten sites analyzed and profiled, only two properties had no reduction in building potential as a result of the buffer scenarios tested (Christine Gardens Apartment and Care and Whitney Public School). The other sites had no reduction in building potential at the 10 metre buffer setback, experienced some reduction at 30 metres and a considerable reduction in building potential at 50 metres. Tables 2.1 and 2.2 illustrate these results.

In order to determine the impact of a 100 metre setback, two sites were chosen: The Ports and Inmont Canada. With respect to the Ports, the total reduction in building value is estimated at $24 million, while the reduction per metre of track is in the order of $488,461.

Meanwhile, Inmont Canada's total reduction in building potential is estimated to be in the order of $2.1 million, with the reduction per metre of track approximately $21,053.

In the industrial zones, the buildings were quite old, containing standard manufacturing uses. In many cases, the buildings are not developed to the maximum height limit. Most of the structures are one storey, indicating an underuse of the property.

Three of the ten sites profiled assumed a redevelopment scenario. These being St. Rita's Catholic School; George Brown College and the Marathon Lands south of The Ports. Local neighbourhood planners from the City of Toronto were contacted to determine the nature and extent of redevelopment for each of the above sites.

Furthermore, site specific developments were utilized in order for the properties designated for redevelopment to be compatible with surrounding landuses, and to represent a marketable final product.

This was the case in calculating buildable area for the George Brown College site, where the new medium-density residential development ("Castle Hill") was used as an example of building form and project character.

With regards to St. Rita's Catholic School, surrounding housing forms were transposed in determining new residential landuses for redevelopment of the school site.

Even though the Ports (1155 and 1177 Yonge Street) did not fall under the influence of the buffer setback, the Marathon Lands to the south did. These lands are an important indication of how buffer setbacks would influence the value of prime redevelopment properties along the Canadian Pacific Railway Corridor. For this reason, the Marathon Lands have been included in this analysis.

The Marathon Lands in question are bounded by Shaftesbury to the north, the Canadian Pacific Railway lands to the south, and Yonge Street to the west, (1131 Yonge Street, 15 and 35 Shaftesbury Avenue).

Local area planners were contacted to the redevelopment potential of these lands, focussing on density, coverage and zoning, in order to arrive at a realistic development scenario.

2.2 CONCLUSIONS

Based on the results in Table 2.3, the 10 meter setback scenario has zero costs associated with its implementation, regardless of landuse. However, the 30 meter setback does impact on surrounding landuses. Across the Canadian Pacific Railway Corridor Line, this is estimated to be in the area of $7 Million ($7,314,000) for industrial, $103 Million ($103,740,380) for commercial, and $57 Million ($57,705,201) for residential, for a total cost of $162 million ($162,759,589).

Logically at 50 meters, the cost is higher since the buffer encroachment is greater on surrounding landuses than the other setbacks. This restricts lot area, and thus reduces total building potential. To this end, the approximate costs associated with the 50 meter buffer scenario are $16 Million ($16,905,600) for industrial, $365 Million ($365,716,094) for commercial and $118 Million ($118,488,000) for residential, for a total cost of $506 million ($506,592,274) across the Canadian Pacific Railway Corridor.

These figures provide a general indication of the capital costs associated with instituting the buffer scenarios, with respect to the various risk profiles identified by Concord Scientific Corporation.

TABLE 2.1

REDUCTION FOR LAND VALUE FOR THE 10 SITES REVIEWED

Site	Zoning	Total Reduction in Value		
		10 Metre Buffer	30 Metre Buffer	50 Metre Buffer
Inmont Canada	Industrial	$0	$169,420	$388,720
National Rubber	Industrial	$0	$0	$400,416
Anchor Cap	Industrial	$0	$0	$1,270,220
Nacan Products	Industrial	$0	$203,992	$424,582
Welder's Supply	Commercial	$0	$720,920	$1,223,950
The Ports	Commercial	$0	$0	$18,715,944
St. Rita's School	Residential	$0	$1,152,000	$2,112,000
George Brown College	Residential	$0	$0	$3,600,000
Whitney Public School	Residential	$0	$0	$0
Christie Garden Apts	Residential	$0	$0	$0

TABLE 2.2

AVERAGE REDUCTION IN TOTAL LAND VALUE PER METRE OF TRACK BY LAND USE

Land Use	Reduction in Land Value Metre of Track		
	10 Metre Buffer	30 Metre Buffer	50 Metre Buffer
Industrial	$0	$2,492	$5,760
Commercial	$0	$36,046	$127,073
Residential	$0	$10,473	$24,000

TABLE 2.3

TOTAL REDUCTION IN LAND VALUE FOR 10 METER BUFFER SETBACK BY OFFICIAL PLAN LANDUSES ACROSS THE CPR CORRIDOR LINE

	Trackage Flanked	Average Reduction Per Meter of Track	Total Cost
Industrial[1)]	2,935 m	$0	$0
Commercial[2)]	2,878 m	$0	$0
Residential	4,937 m	$0	$0
TOTAL	10,750 m		$0

AVERAGE COST OF 30 METER BUFFER SETBACK BY OFFICIAL PLAN LANDUSES ACROSS THE CPR CORRIDOR LINE

	Trackage Flanked	Average Reduction Per Meter of Track	Total Cost
Industrial[1)]	2,935 m	$2,492	$7,314,000
Commercial[2)]	2,878 m	$36,046	$103,740,388
Residential	4,937 m	$10,473	$51,705,201
TOTAL	10,750 m		$162,759,589

AVERAGE COST OF 50 METER BUFFER SETBACK BY OFFICIAL PLAN LANDUSES ACROSS THE CPR CORRIDOR LINE

	Trackage Flanked	Average Reduction Per Meter of Track	Total Cost
Industrial[1)]	2,935 m	$5,760	$16,905,600
Commercial[2)]	2,878 m	$127,073	$365,716,094
Residential	4,937 m	$24,000	$118,488,000
TOTAL	10,750 m		$501,109,694

1) Includes warehousing and storage uses.
2) Includes office uses.

PROPERTY FACT SHEET

Site: Inmont Canada

Address: 1444 Dupont Street

Total Floor Area: 9,331 sq. m

Lot Area: 9,400 sq. m

Zoning: I_2 D_2

Permitted Uses: manufacturing, warehousing, storage, utilities and incidental commercial and institutional uses

Coverage: 2 x the area of the lot

Height Limit: 14 metres

Setbacks: 3 metres from a residential zone

Maximum Lot Area Coverage: 18,800 sq. m
(Lot Area x Coverage)

Maximum Ground Floor Building Area: 8,160 sq. m
(After Setbacks)

SITE: INMONT CANADA

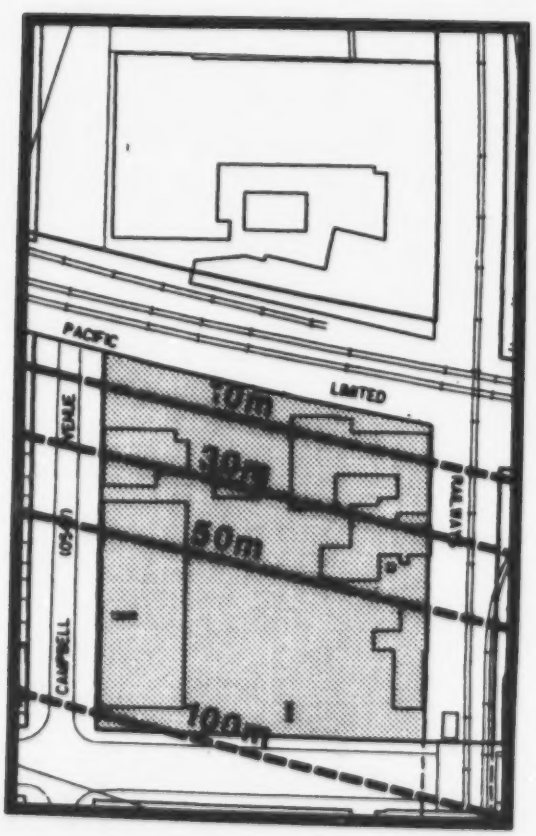
MAXIMUM LOT AREA COVERAGE: 18,800 SQ. METRES

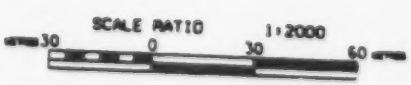
Buffer (m)	Max. Permitted Footprint (sq. m)	Max. Bldg. Area (sq. m)			Reduction in Bldg. Potential (sq. m)
		1 Storey	2 Storeys	3 Storeys	
0	8,160	8,160	16,320	24,480	0
10	7,310	7,310	14,620	21,930	0
30	5,610	5,610	11,220	16,830	1,970
50	4,760	4,760	9,520	14,280	4,520

Site: Inmont Canada
Zoning: Industrial

	Buffer Setback		
	10 Metres	30 Metres	50 Metres
Reduction in Total Value	$0	$169,420	$388,720
Metres of Tracks	100	100	100
Reduction in Total Value per Metre of Track	$0	$1,694	$3,887

SITE PLAN





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PROPERTY FACT SHEET

Site: National Rubber (Symington Facility)

Address: 386 Symington Avenue

Total Floor Area: 9,368 sq. m.

Lot Area: 7,123 sq. m.

Zoning: I_2 D_2 (recommended by the City of Toronto's Planning Dept. for Council approval)

Permitted Uses: manufacturing, warehousing, storage, utilities and incidental commercial and institutional uses

Coverage: 2 x the area of the lot

Height Limit: 14 metres

Setbacks: 3 metres from a residential zone

Maximum Lot Area Coverage: 14,246 sq. m.
(Lot Area x Coverage)

Maximum Ground Floor Building Area: 5,450 sq. m.
(After Setbacks)

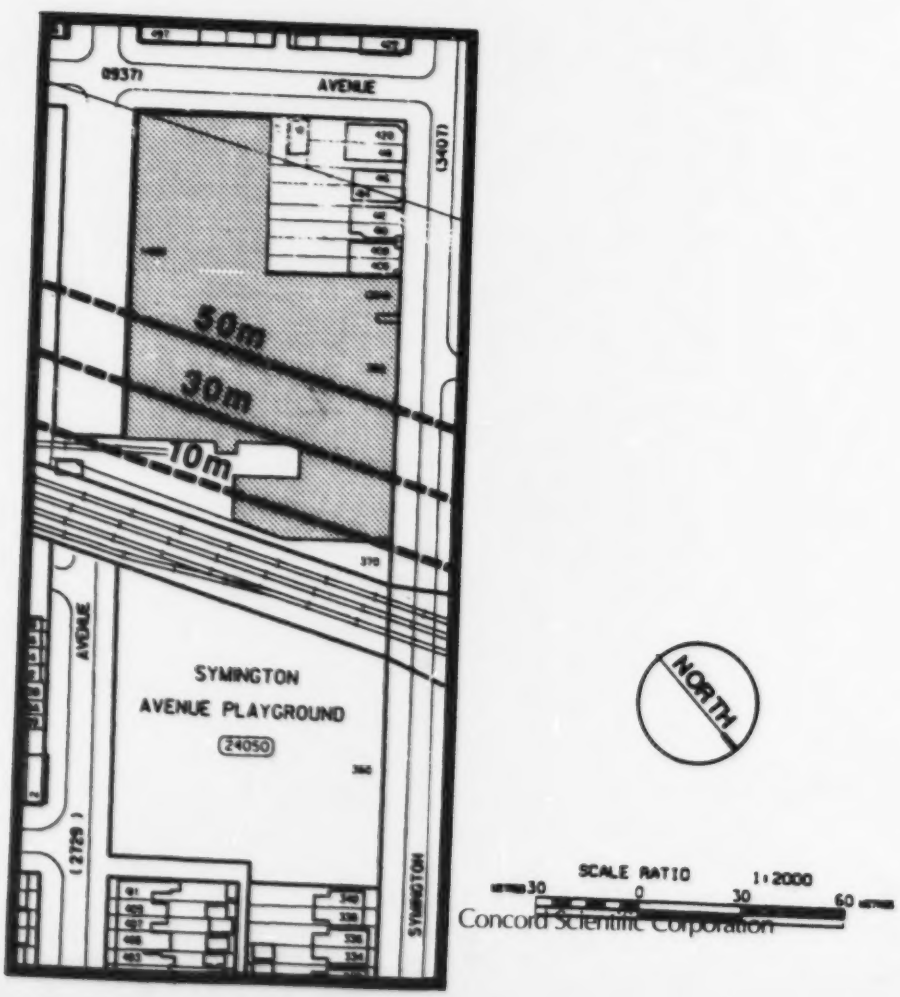
SITE: NATIONAL RUBBER (SYMINGTON FACILITY)
MAXIMUM LOT AREA COVERAGE: 14,246 SQ. METRES

Buffer (m)	Max. Permitted Footprint (sq. m)	Max. Bldg. Area (sq. m)			Reduction in Bldg. Potential (sq. m)
		1 Storey	2 Storeys	3 Storeys	
0	5,450	5,450	10,900	16,350	0
10	5,300	5,300	10,600	15,900	0
30	4,895	4,895	9,790	14,685	0
50	3,308	3,308	6,616	9,924	4,340

Site: National Rubber
Zoning: Industrial

	Buffer Setback		
	10 Metres	30 Metres	50 Metres
Reduction in Total Value	$0	$0	$400,416
Metres of Tracks	80	80	80
Reduction in Total Value per Metre of Track	$0	$0	$5,005

SITE PLAN



PROPERTY FACT SHEET

Site: Anchor Cap and Closures

Address: 275 Wallace Avenue

Total Floor Area: 7,686 sq. m.

Lot Area: 13,685 sq. m.

Zoning: I_2 D_2

Permitted Uses: manufacturing, warehousing, storage, utilities and incidental commercial and institutional uses

Coverage: 2x the area of the lot

Height Limit: 14 metres

Setbacks: 3 metres from a residential zone

Maximum Lot Area Coverage: 27,370 sq. m.
(Lot Area x Coverage)

Maximum Ground Floor Building Area: 12,250 sq. m.
(After Setbacks)

SITE: ANCHOR CAP & CLOSURES

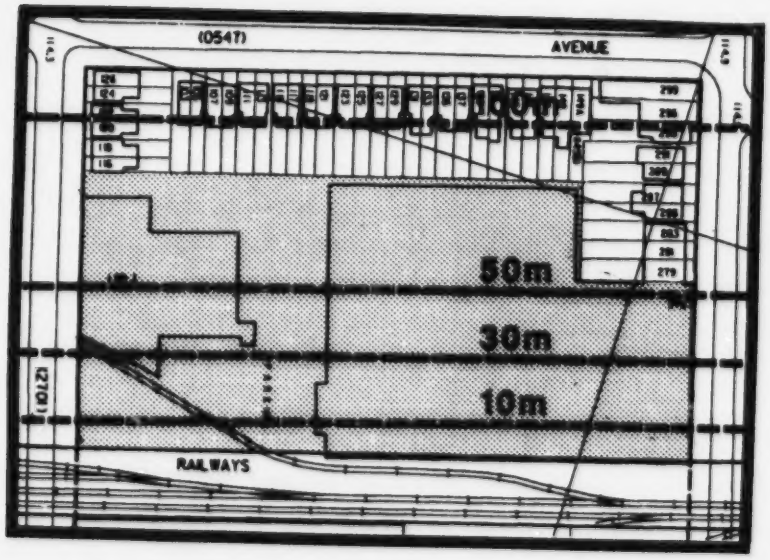
MAXIMUM LOT AREA COVERAGE: 27,370 SQ. METRES

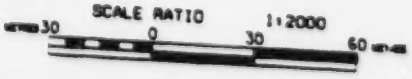
Buffer (m)	Max. Permitted Footprint (sq. m)	Max. Bldg. Area (sq. m)			Reduction in Bldg. Potential (sq. m)
		1 Storey	2 Storeys	3 Storeys	
0	12,250	12,250	24,500	36,750	0
10	11,375	11,375	22,750	34,125	0
30	9,625	9,625	19,250	28,875	0
50	4,200	4,200	8,400	12,600	14,770

Site: Anchor Cap & Closures
Zoning: Industrial

	Buffer Setback		
	10 Metres	30 Metres	50 Metres
Reduction in Total Value	$0	$0	$1,270,220
Metres of Tracks	174	174	174
Reduction in Total Value per Metre of Track	$0	$0	$14,770

SITE PLAN





Concord Scientific Corporation

PROPERTY FACT SHEET

Site: Nacan Products Limited

Address: 371 Wallace Avenue

Total Floor Area: 3,911 sq. m.

Lot Area: 3,238 sq. m.

Zoning: I_2 D_2

Permitted Uses: manufacturing, warehousing, storage, utilities, and incidental commercial and institutional uses

Coverage: 2x the area of the lot

Height Limit: 14 metres

Setbacks: 3 metres from a residential zone

Maximum Lot Area Coverage: 6,476 sq. m.
(Lot Area x Coverage)

Maximum Ground Floor Building Area: 3,078 sq. m.
(After Setbacks)

SITE: NACAN PRODUCTS LIMITED

MAXIMUM LOT AREA COVERAGE: 6,476 SQ. METRES

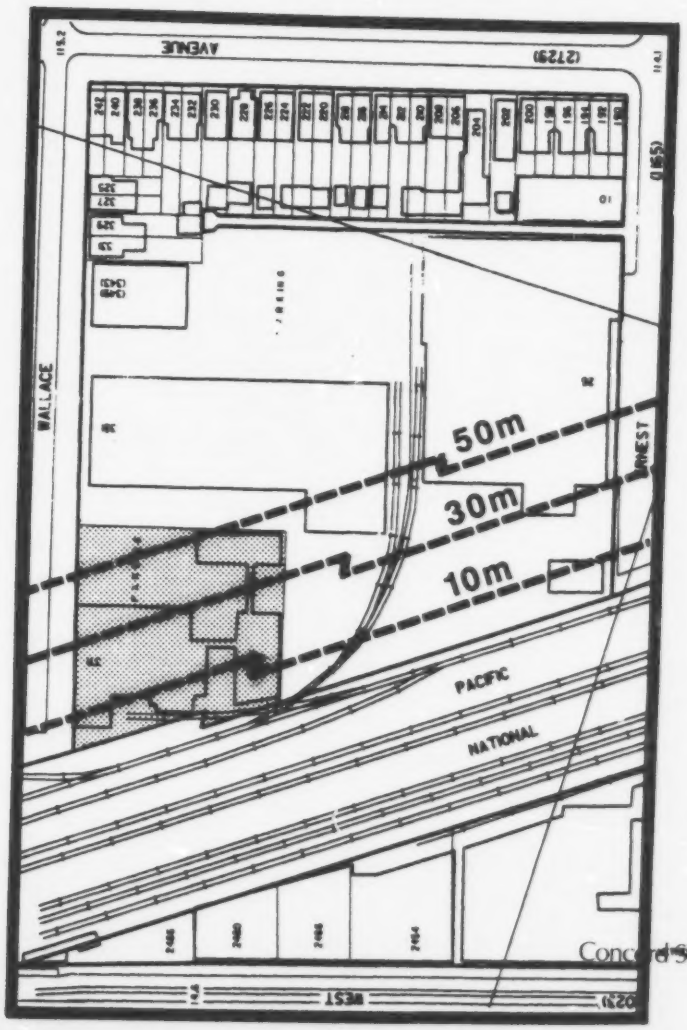
Buffer (m)	Max. Permitted Footprint (sq. m)	Max. Bldg. Area (sq. m)			Reduction in Bldg. Potential (sq. m)
		1 Storey	2 Storeys	3 Storeys	
0	3,078	3,078	6,156	9,234	0
10	2,508	2,508	5,016	7,524	0
30	1,368	1,368	2,736	4,104	2,372
50	513	513	1,026	1,539	4,937

Site: Nacan Products Limited

Zoning: Industrial

	Buffer Setback		
	10 Metres	30 Metres	50 Metres
Reduction in Total Value	$0	$203,992	$424,582
Metres of Tracks	62	62	62
Reduction in Total Value per Metre of Track	$0	$3,290	$6,848

SITE PLAN



Concord Scientific Corporation

PROPERTY FACT SHEET

Site: Welder's Supply

Address: 1 Popular Plains Road (307 Macpherson Avenue)

Total Floor Area: Not Available

Lot Area: 660 sq. m.

Zoning: C_2 V_2

Permitted Uses: Service Retail, Storage, Manufacturing

Coverage: 5 x the area of the lot

Height Limit: None

Setbacks: 3 metres from a residential zone

Maximum Lot Area Coverage: 3,050 sq. m.
(Lot Area x Coverage)

Maximum Ground Floor Building Area: 455 sq. m.
(After Setbacks)

SITE: WELDER'S SUPPLY

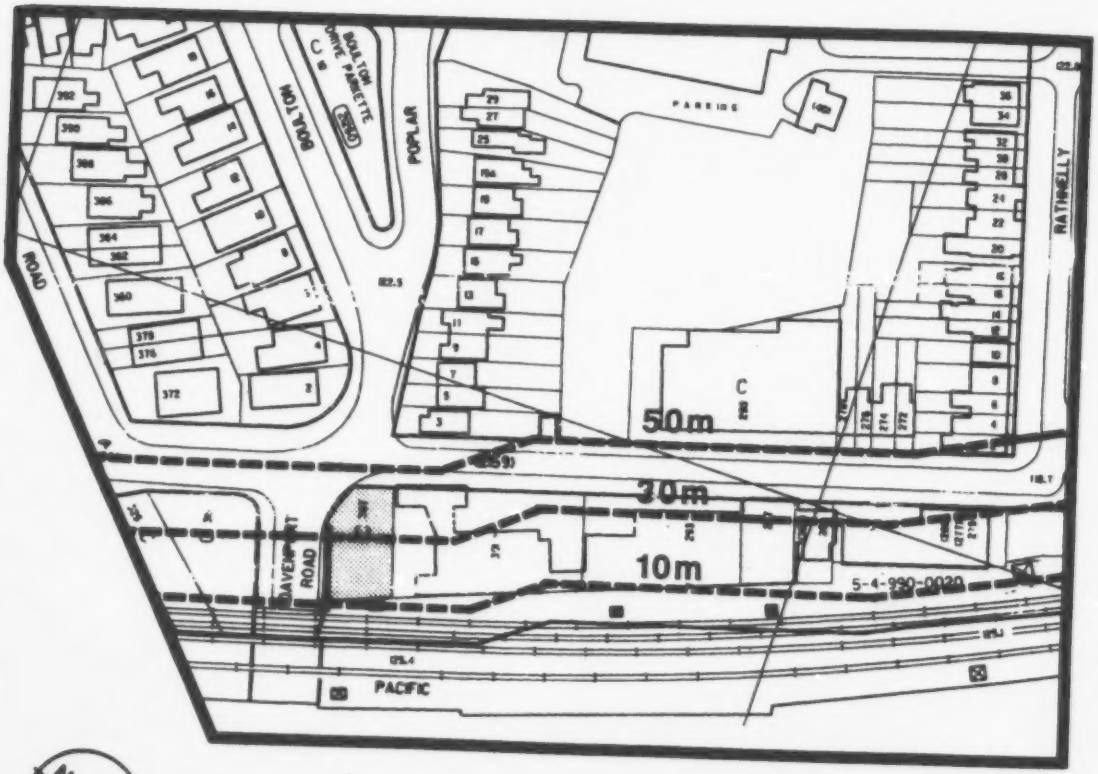
MAXIMUM LOT AREA COVERAGE: 3,300 SQ. METRES

Buffer (m)	Max. Permitted Footprint (sq. m)	Max. Bldg. Area (sq. m)					Reduction in Bldg. Potential (sq. m)
		1 Storey	2 Storeys	3 Storeys	4 Storeys	5 Storeys	
0	455	455	455	1,365	1,820	2,275	0
10	455	455	910	1,365	1,820	2,275	0
30	187	187	374	561	748	935	1,340
50	0	0	0	0	0	0	2,275

Site: Welder's Supply
Zoning: Commercial

	Buffer Setback		
	10 Metres	30 Metres	50 Metres
Reduction in Total Value	$0	$720,920	$1,223,950
Metres of Tracks	20	20	20
Reduction in Total Value per Metre of Track	$0	$36,046	$61,198

SITE PLAN



Concord Scientific Corporation

PROPERTY FACT SHEET

Site: The Ports

Address: 1155 & 1177 Yonge Street

Total Floor Area:
1133 Yonge Street - 5,304 sq. m
1155 Yonge Street - 8,019 sq. m
1177 Yonge Street - 22,233 sq. m
1133 Yonge Street - 1,250 sq. m

Lot Area:
1133 Yonge Street - 1,280 sq.m
1155 Yonge Street - 1,372 sq.m
1177 Yonge Street - 3,558 sq. m

Zoning: Site Specific By-Law 286-83

Permitted Uses: residential and commercial mixed use building.

Height Limit: 21.5 metres

Maximum Lot Area Coverage: Site Specific By-Law 286-83

Maximum Ground Floor Building Area: (After Setbacks)
1133 Yonge Street - 884 sq. m
1155 Yonge Street - 800 sq. m
1177 Yonge Street - 2,375 sq. m

Note: The development scenario for lands fronting onto the south side of Shaftesbury Avenue, west of Shaftesbury Place (1133 and 1131 Yonge Street, 15 and 35 Shaftesbury Avenue) have been developed for commercial offices at a density, scale and mass of building compatible with the structure on 1133 Yonge Street, including sufficient on-site parking.

This is based on the Proposals Report: "Review of the Land Use Planning Policies for the block bounded by Shaftesbury Avenue, Yonge Street, Prize Street and the Vale of Avoca", 623/008059, February 17, 1989.

SITE: THE PORTS

1133 Yonge Street

Buffer (m)	Max. Permitted Footprint (sq. m)	Max. Bldg. Area (sq. m)						Reduction in Bldg. Potential (sq. m)
		1 Storey	2 Storeys	3 Storeys	4 Storeys	5 Storeys	6 Storeys	
0	884	884	1,768	2,652	3,536	4,420	5,304	0
10	884	884	1,768	2,652	3,536	4,420	5,304	0
30	884	884	1,768	2,652	3,536	4,470	5,304	0
50	637	637	1,274	1,911	2,548	3,185	3,822	1,482

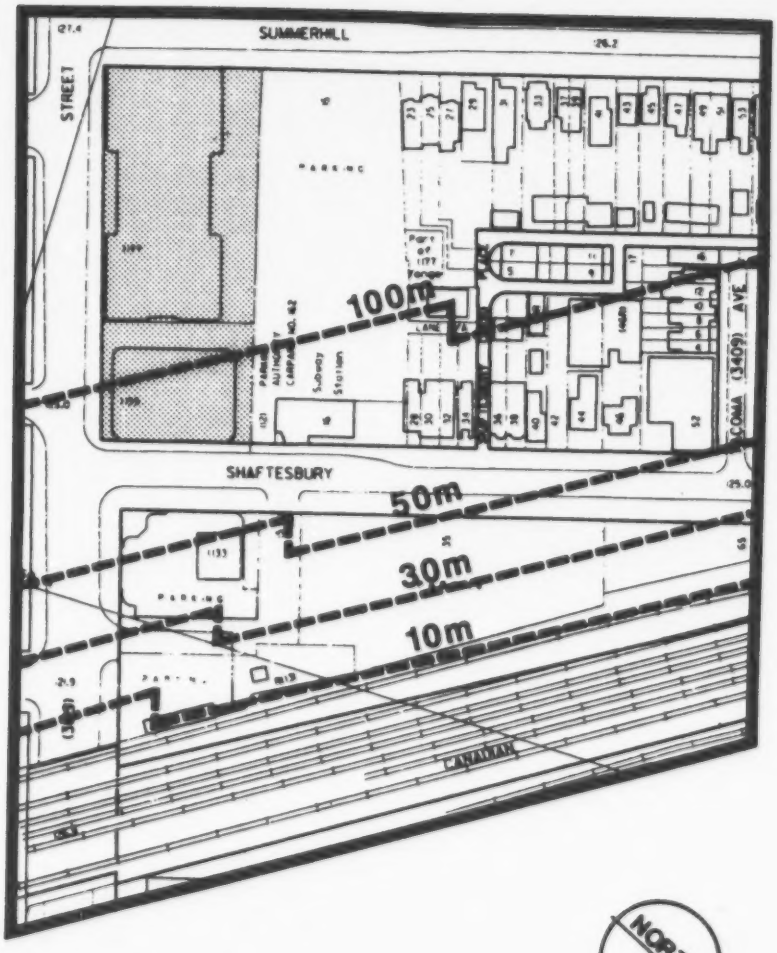
1131 Yonge Street 15 & 35 Shaftesbury Avenue* (Marathon Lands North of the CPR Line)

Buffer (m)	Max. Permitted Footprint (sq. m)	Max. Bldg. Area (sq. m)**						Reduction in Bldg. Potential (sq. m)
		1 Storey	2 Storeys	3 Storeys	4 Storeys	5 Storeys	6 Storeys	
0	2,652	2,652	5,304	7,956	10,608	13,260	15,912	0
10	2,652	2,652	5,304	7,956	10,608	13,260	15,912	0
30	2,652	2,652	5,304	7,956	10,608	13,260	15,912	0
50	0	0	0	0	0	0	0	15,912

* Based on discussions with local area planners and the following Land Use Committee Proposals Report: "Review of the Land Use Planning Policies for the block bounded by Shaftesbury Avenue, Yonge Street, Price Street and the Vale of Avoca", 623/088059, February 17, 1989.

** Development concept consists of 3-6 storey office buildings.

SITE PLAN



Concord Scientific Corporation

PROPERTY FACT SHEET

Site: St. Rita's Catholic School

Address: 176 Edwin Avenue

Total Floor Area: 3,888 sq. m. (School Building)

Lot Area: 9,135 sq. m.

Zoning: R_2 Z0.6

Permitted Uses: residential

Coverage: 0.6 x the area of the lot

Height Limit: 12 metres

Setbacks: 3 metres from a residential zone

Maximum Lot Area Coverage: 5,481 sq. m.
(Lot Area x Coverage)

Maximum # of Lots Permitted: 43 (semi-detached)

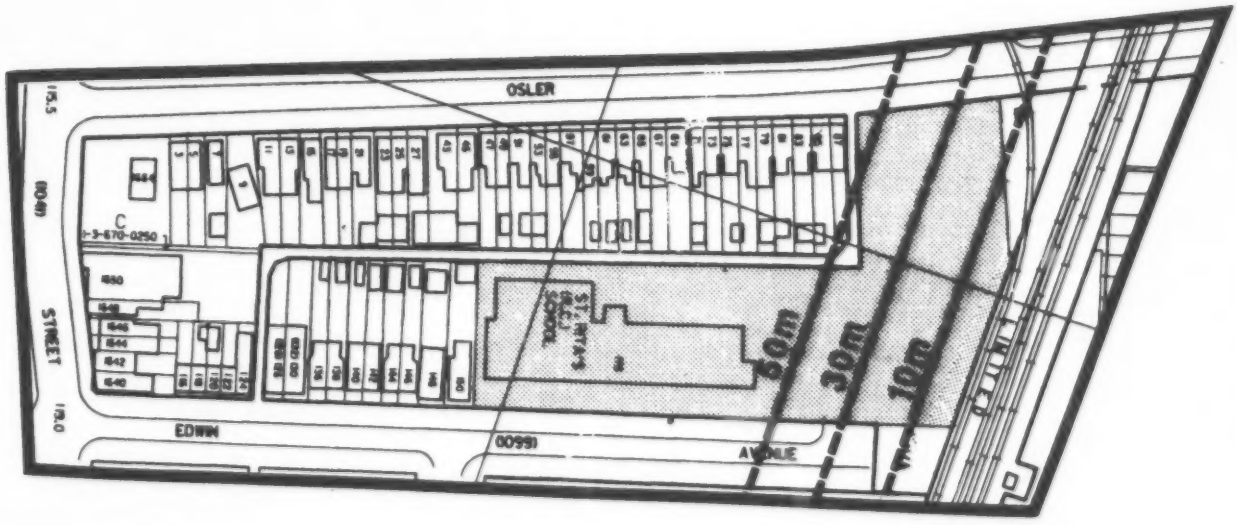
SITE: ST. RITA'S CATHOLIC SCHOOL
MAXIMUM LOT AREA: 9,135 SQ. METRES

Buffer (m)	Max Lot Area (sq. m)	Max. Permitted Footprint (sq. m)	Reduction in Max. Bldg. Potential (sq. m)
0	9,135	9,135	0
10	8,485	8,485	0
30	6,260	6,260	2,400
50	4,285	4,285	4,400

Site: St. Rita's Catholic School
Zoning: Residential

	Buffer Setback		
	10 Metres	30 Metres	50 Metres
Reduction in Total Value	$0	$1,152,000	$2,112,000
Metres of Tracks	110	110	110
Reduction in Total Value per Metre of Track	$0	$10,473	$19,200

SITE PLAN



Concord Scientific Corporation

PROPERTY FACT SHEET

Site: George Brown College

Address: 146 Kendal Avenue

Total Floor Area: 46,206 sq. m.

Lot Area: 20,832 sq. m.

Zoning: QR L2.5 U200

Permitted Uses: local retail and service commercial, residential, general institutional and community services

Coverage: Residential - 200 units per ha.

Height Limit: 14 metres

Setbacks: 3 metres from a residential zone

Maximum Lot Area Coverage: 52,080 sq. m.
(Lot Area x Coverage)

Maximum Ground Floor Building Area: Residential - 700 sq. m (7 blocks @ 1,000 sq. m each)
(After Setbacks)

SITE: GEORGE BROWN COLLEGE

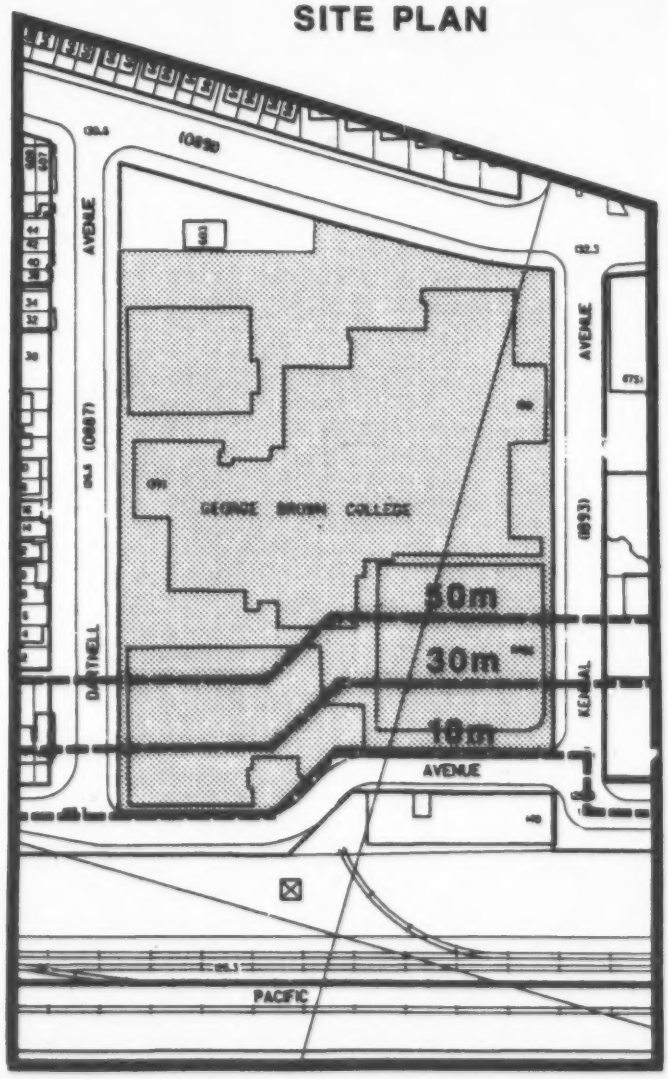
MAXIMUM LOT AREA COVERAGE: 7,000 SQ. METRES

Buffer (m)	Max. Permitted Footprint (sq. m)	Max. Bldg. Area @ 4 Storeys (sq. m)	Reduction in Bldg. Potential (sq. m)
0	7,000	28,500	0
10	7,000	28,500	0
30	7,000	28,500	0
50	6,000	24,526	3,974

Site: George Brown College
Zoning: Residential

	Buffer Setback		
	10 Metres	30 Metres	50 Metres
Reduction in Total Value	$0	$0	$3,600,000
Metres of Tracks	125	125	125
Reduction in Total Value per Metre of Track	$0	$0	$28,800

SITE PLAN



Concord Scientific Corporation

PROPERTY FACT SHEET

Site: Whitney Public School

Address: 119 Rosedale Heights Drive

Total Floor Area: 5,679 sq. m. (School Building)

Lot Area: 11,820 sq. m.

Zoning: R_2 Z0.6

Permitted Uses: residential

Coverage: 0.6 x the area of the lot

Height Limit: 10.7 metres

Setbacks: Minimum lot frontages of 12 metres from detached and 9 metres for semi-detached

Maximum Lot Area Coverage: 7,092 sq. m.
(Lot Area x Coverage)

Maximum # of Lots Permitted: 19 (detached)

SITE: WHITNEY PUBLIC SCHOOL

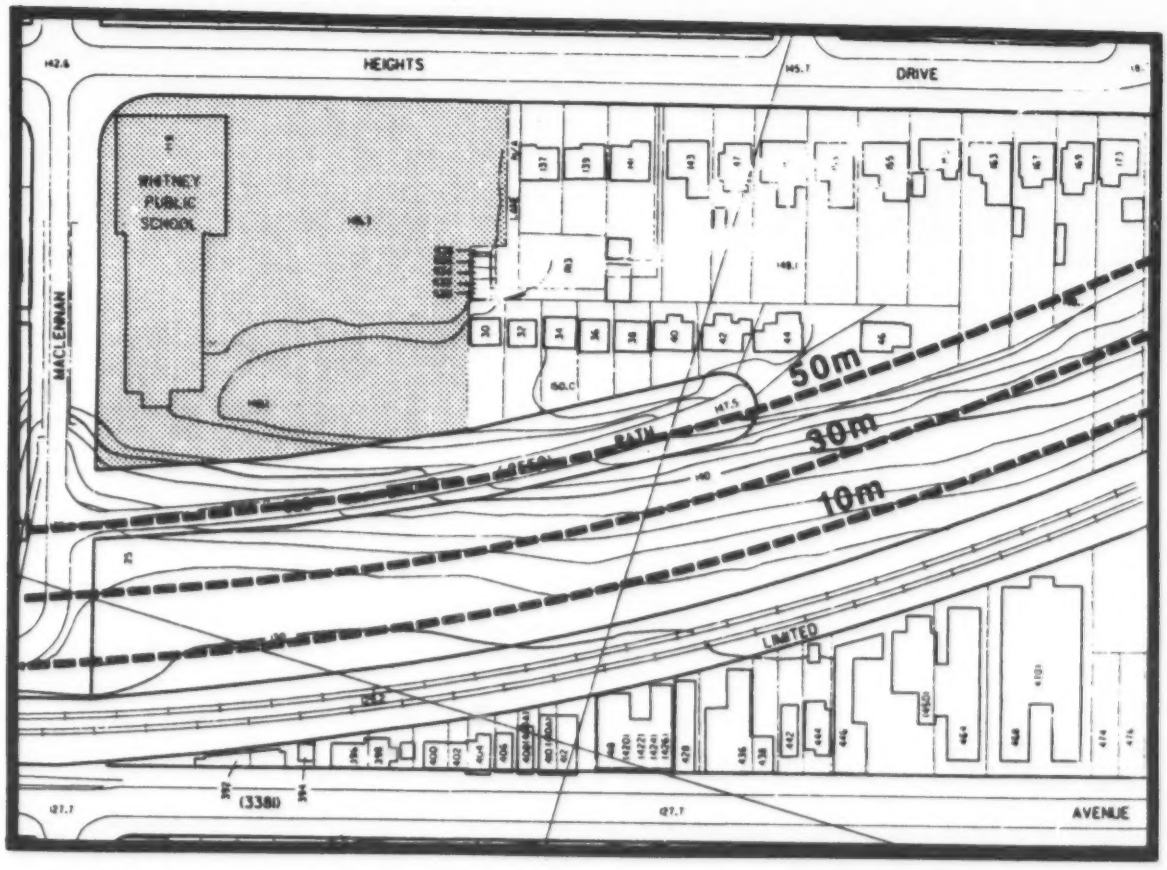
MAXIMUM LOT AREA COVERAGE: 7,092 SQ. METRES

Buffer (m)	Max. Lot Area (sq. m)	Max. Permitted Footprint (sq. m)	Reduction in Max. Bldg. Potential (sq. m)
0	11,820	7,092	0
10	11,820	7,092	0
30	11,820	7,092	0
50	11,820	7,092	0

Site: Whitney Public School
Zoning: Residential

	Buffer Setback		
	10 Metres	30 Metres	50 Metres
Reduction in Total Value	$0	$0	$0
Metres of Tracks	73	73	73
Reduction in Total Value per Metre of Track	$0	$0	$0

SITE PLAN



Concord Scientific Corporation

PROPERTY FACT SHEET

Site: Christie Gardens Apartments and Care

Address: 600-602 Melita Crescent

Total Floor Area: 19,001 sq. m.

Lot Area: 8,319 sq. m.

Zoning: R_2 Z1.0

Permitted Uses: residential

Coverage: 1.0 x the area of the lot

Height Limit: 10 metres

Setbacks: 3 metres from a residential zone

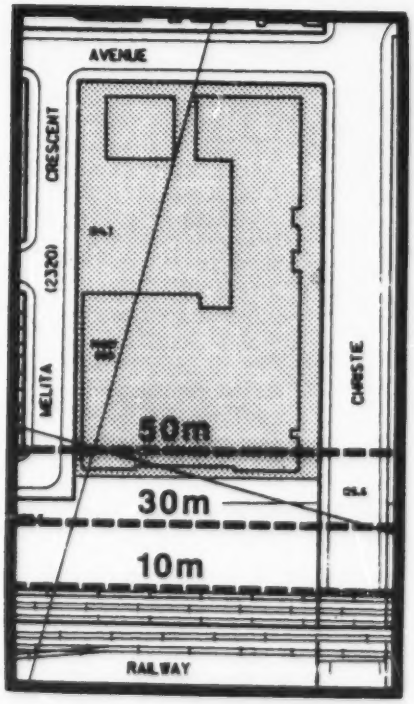
Maximum Lot Area Coverage: 8,319 sq. m.
(Lot Area x Coverage)

Maximum Ground Floor Building Area: 7,150 sq. m.
(After Setbacks)

SITE: CHRISTIE GARDENS APARTMENTS AND CARE
MAXIMUM LOT AREA COVERAGE: 8,319 SQ. METRES

Buffer (m)	Max. Permitted Footprint (sq. m)	Max. Bldg. Area (sq. m)		Reduction in Bldg. Potential (sq. m)
		1 Storey	2 Storeys	
0	7,150	7,150	14,300	0
10	7,150	7,150	14,300	0
30	7,150	7,150	14,300	0
50	6,630	6,630	13,260	0

Site: Christie Garden Apartments & Care
Zoning: Residential

	Buffer Setback		
	10 Metres	30 Metres	50 Metres
Reduction in Total Value	$0	$0	$0
Metres of Tracks	110	110	110
Reduction in Total Value per Metre of Track	$0	$0	$0

SITE PLAN